DOCUMENT RESUME

ED 301 153 IR 013 493

AUTHOR	Zellner, Ronald D., Ed.; And Others
TITLE	Technology in Education: Implications and Applications.
INSTITUTION	Texas A and M Univ., College Station. Instructional Research Lab.
PUB DATE	87
NOTE	144p.
PUB TYPE	Collected Works - General (020) -- Reports - Research/Technical (143)
EDRS PRICE	MF01/PC06 Plus Postage.
DESCRIPTORS	*Cognitive Processes; *Computer Assisted Instruction; *Computer Oriented Programs; Database Management Systems; *Educational Research; *Educational Technology; Elementary Secondary Education; *Microcomputers; Reading Instruction; Telecommunications

ABSTRACT

Nine of the 15 papers in this collection consider the current uses of technology in education and the implications of this use; the six remaining papers focus on applications of technology in education. The papers are: (1) "A Qualitative Synthesis of Pictorial Complexity on Learner Achievement" (Jay Angert, Jon Denton, and Francis Clark); (2) "Information Management in Our Schools: A Time for Change" (Leonard Lindstrom); (3) "A Systematic Approach to the Development of Campus Level Administrative Information Management Systems" (Steve Wilson); (4) "Defining the Role of Calculators and Computers in the Learning and Teaching of Secondary School Mathematics" (Robert Kansky); (5) "Telecommunications: Applications and Considerations for Use" (Jon Denton, Michael O'Connor, and Robert Rossing); (6) "Educational Computing: A Good Buy for K-12 Education? Maybe Not" (Michael Burger); (7) "Selected Research on Computer-Assisted Instruction in Reading" (Barbara Schaudt); (8) "Computer Application in Second-Language Learning" (Viola Flores-Tighe and David Zuflet); (9) "Teaching the Handicapped and Disadvantaged via Computer: What We Have Learned from Field Research" (Carol Anderson and Donna Norton); (10) "A Systems Approach for the Development of Computer-Based Instruction in Primary Grades, Heart Health Curriculum" (Sue Beall); (11) "Monitoring Student Progress with Microcomputers" (Maynard Bratlien and Beth Taylor); (12) "Computer-Based Testing with Young Children" (Brooks Applegate, Patricia Alexander, and Victor Willson); (13) "Encoding and Retrieval Process in the Spatial Memory Performance of Adults" (Robert Hall, Ernest Goetz, Steven Eckert, Michael Stowe, and Suzanne Kangiser); (14) "An Illustrative Application of Microcomputer Technology to the Study of Reading" (Douglas Palmer, Jean Kueker, and Michael Stowe); and (15) "Manipulating Quantitative Data with a Data Management System or Replacing the Shoe Box with the Microcomputer" (Robert Fellenz and Gary Conti). The text is supplemented by various tables and figures, and each paper contains a list of references. (EW)

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ACKNOWLEDGEMENT

We would like to express our thanks to those who assisted in the production of this volume: the Steering Committee on Fostering Educational Inquiry for project funding, and Laura Knowles and Louis Lucko for keyboarding and layout.

TECHNOLOGY IN EDUCATION: IMPLICATIONS AND APPLICATIONS

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A publication of the Instructional Research Laboratory of the Department of Educational Curriculum and Instruction, under a grant from the Steering Committee to Foster Educational Inquiry, College of Education, Texas A&M University, College Station, Texas 77843

Instructional Research Laboratory
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College Station, Texas
1987

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FOREWORD

Research university centers, like Texas A&M University, can make a major contribution by inquiring into educational technology and discovering new applications to improve learning and teaching. This publication synthesizes the results of scholarly investigations about technology in ways that are useful to professional practitioners and the people they serve.

Much still needs to be done to develop a pedagogy to accompany modern technology. With the exception of a few schools, usually in affluent communities, most still look like those of the 1950's and 1960's. I am constantly struck by the sameness of schools. Most schools have little to show in the way of technological innovation beyond the presence of a number of computers and televisions being used to support traditional structures. Few educational institutions have used technology to produce drastic changes in instruction and learning or reconstruct school or classroom organization and management.

The possibilities that exist in the continued development of educational technology in schools, at the work place, and in the home are immense. Electronic education tools have great potential to become more than 'pretty toys.' Appropriately developed and used, the new technology can help students think more clearly, write more cogently, use facts more effectively and analyze ideas and solve problems better. But, research and development must produce innovative pedagogy to match innovative technology.

This publication adds some new perspectives to current discussions of school improvement and highlights the special place technology should have on the agenda for educational reform. I am pleased that faculty and students at Texas A&M are participating actively in this inquiry activity.

Dean C. Corrigan
Dean, College of Education
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INTRODUCTION

As technological advances have been made throughout history the relative benefits have been extended to a wide variety of human endeavors and activities. Cultural advances have been closely tied to general technological developments, each having a profound influence on the other. As technologies have emerged, societies have responded by changing to incorporate the technology or its products. This response and adaptation then exerts an influence over the continuation of the technological advance, as well as the development of subsequent new areas. The widespread availability of inexpensive electricity is an excellent example of this interaction and its continuing effects.

Education is one of those areas that has experienced the influence of such technological advances. While most technological developments have not been designed specifically for educational applications, current educational practices and structures would certainly not have evolved beyond very basic levels without the continued incorporation of existing technologies. Conversely, technological advances have enhanced our understanding of the world around us and dramatically extended the body of known information. This technology and the information base it has produced forms the subject matter for which educators must develop materials and subsequently teach, further perpetuating the technology-culture cycle by providing future generations of technologically proficient individuals. Thus, education, technology and society are intertwined in a complex, interdependent web of mutual evolution.

The interrelationship of these areas is readily understood in the context of the definition of technology as: 'the development of materials and devices which enhance or amplify human abilities.' In this context, technological advances are the result of the development of ways for individuals to do activities: more quickly, with more power, to a greater extent, for prolonged periods of time, etc.. These enhancements of human ability can be categorized into three major, interdependent areas: the enhancement of physical ability, the enhancement of sensory ability, and the enhancement of intellectual ability. Educational technology applications are primarily related to the last two of these categories, sensory and intellectual enhancements. While such applications have their roots in the development and utilization of printed material, current technological applications are focused on the more complex electronic technologies and related developments. The primary goal in this area

is to develop teaching materials and techniques which utilize the power of current technologies to enhance the teaching/learning process. In this context the technologies have no value in and of themselves, but must be integrated within the complex structure of educational research, practice and applications. Consequently, there is a pronounced need to prepare educators who are well versed in the use of technologies and their potential utility. This need pertains to the full range of activities within the College of Education and applies to teacher preparation students, in-service teachers, graduate students, and university faculty.

The area of educational technology and its applications includes instructional design theory and techniques which relate to the following: printed materials, photography, graphics, television, computers and telecommunications. Due to the current widespread interest in computers, as well as the recent dramatic growth in the quality and quantity of computers and related applications, the articles in this monograph are somewhat concentrated on this area of technology, reflecting the interest and activities of the contributors. The computer, and its related software and devices, offers a wide variety of potential applications and tools to educational practice. This technology provides not only a powerful means of teaching and distributing information, but a powerful tool for easy acquisition and analysis of information in a variety of educational and research settings. It is important that educational practitioners and researchers are involved in the development of this potential to insure the appropriateness and validity of future applications and to tap the full potential that this technology offers.

It is our intent here to help develop an awareness of the current uses of technology as well as an awareness of potential applicability to the needs and activities of the reader. We hope that this information will help to foster effective use of technology in the everyday classroom and research practices of faculty and students. While there is an emphasis on computer applications in the articles which follow, there remains a definite need for the full range of technological applications in educational practice, including the integration of these areas for further enhancement of educational effectiveness. The development of interactive video materials for teaching in a variety of topic areas provides a good example of such integration. In general, the sequence of articles presents a flow from general implications and concerns to applications of technology as a means of solving specific problems or meeting specific needs. A brief delineation of the organization and content follows:

Implications

The first set of papers presents research summaries of technology within specific educational domains and suggest guidelines for new or modified uses of technology in education.

Implications for the use of technolog is introduced through a meta-analysis by Angert, Denton and Clark of research on pictorial complexity which relates to the use of graphics in delivering instruction through textbooks, video, or computer display. A related area is addressed by Lindstrom who presents the computer as a means of supporting the instructional process by releasing teachers from low-level supervisory duties associated with instruction (e.g., record keeping, reporting, scheduling) and maximizing teacher involvement in such high-level professional activities as planning, organizing, and directing instruction. The Wilson paper on information management systems extends this computer support component to positions and activities associated with administrative functions. Kansky's analysis of the nature of the tasks presented in doing and teaching secondary mathematics leads to the proposing of guidelines for the appropriate instructional uses of three technological tools: calculators, microcomputers, and paper-pencil.

Implications from past uses of technology include a paper by Denton, O'Connor and Rossing which highlights lessons learned from the application of telecommunications within the business environment. Other implications are treated in Burger's summary of CAI applications and the difficulties of applying cost-effectiveness criteria to CAI studies. His paper leads to a proposal that the greatest current potential for computer applications is the improvement of instructional quality and efficiency through the use of information management systems.

The adaptation of technology to particular tasks is introduced by Schaudt with a presentation of studies utilizing computers to duplicate standard activities within reading instruction. The reviewed examples of attempts to adapt familiar procedures to fit this new medium presents results which are mixed and lack focus. In a review of studies applying computers to second language instruction Flores-Tighe and Zuflet conclude that researchers appear to be developing and capitalizing upon special features of the computer to expand the teaching environment. Anderson and Norton conclude that applications of the computer to special education are mainly focused upon instructional management programs designed to increase teacher efficiency or upon increasing student control of the environment through computer-designed devices related to specific special needs.

Applications

The second section focuses more on applications of technology which provide detailed examples of specific techniques and/or problems associated with applications of technology to teaching or educational research.

Concerns related to instructional applications are presented by Beall in a description of a procedure used in managing the development of microcomputer-based instructional courseware. A report by Bratlien and Taylor follows which presents initial efforts to use microcomputers to monitor student progress within a mastery-learning curriculum.

The next paper presents technological applications to research issues and tasks. Applegate, Alexander and Willson examine the use of the computer as an alternative mode for presenting analogical reasoning tasks to young children. Hall, Goetz, Eckert and Stowe have introduced methodological advantages gained through the incorporation of technologies to provide both quantitative and qualitative improvements in data collection. Their application to research on encoding and retrieval processes provides an excellent illustration of the relative benefits of such applications and the subsequent results obtained. The report by Palmer, Kueker and Stowe extends this illustration to procedures which record and analyze look-back patterns of persons reading passages of varying complexity and provides a discussion of the resulting identified specific differences in the text-processing procedures of good and poor readers. The final report by Conti and Fellenz presents an illustration of incorporating word-processing and database utilities to provide a more efficient exploration of data gathered in qualitative research.

R.D.Z.
J.J.D.
M.L.B.
R.J.K.
August, 1987

A QUANTITATIVE SYNTHESIS OF PICTORIAL COMPLEXITY ON LEARNER ACHIEVEMENT

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Two exasperating problems plague researchers within the applied field of educational technology. First, instructional media research has created a sizable literature but this literature has offered few stable findings. Inadequate conceptualization of experimental variables has been blamed frequently for the conflicting media research results. Second, there appears to be a decreasing relation between communication theory and educational technology research. By not considering media research variables in terms of symbol systems and coding elements, educational technology researchers have not capitalized often on the commonalities that exist among communication models. As a consequence, guidelines for the selection or design of instructional materials are often imprecise or contradictory. One proposed solution for these problems has been to increase the emphasis on research which generates hypotheses. Accordingly, Burton (1979) proposed a decreased emphasis on confirmatory research which tests hypotheses and suggested that the requisite "sorting out" urged by MacDonald-Ross and Smith (1977) could be accomplished through exploratory research which generates hypotheses through an examination of existing research data. Stated another way, research synthesis has been suggested as a methodology for establishing new directions for media research.

Some researchers, (e.g., Dwyer, 1978; Samuels, 1970), have synthesized the results of research on the realism/relevant cue controversy in a qualitative fashion. As is typical of narrative literature reviews, many of the conclusions which have been drawn on this subject are frequently vague and lack quantitative precision (Clark & Angert, 1980). The series of studies undertaken by Dwyer (1978) and colleagues is unique for its consistency, number of related treatments, and longevity in investigating pictorial stimulus complexity as it relates to static instructional visuals. Yet reviews of this body of research have not emphasized a quantitative review of pictorial effectiveness. This methodology was deemed to be a useful adjunct in guiding future empirical efforts in media research.

PURPOSE OF THE STUDY

Although Glass (1977) has suggested that meta-analysis methodology is particularly appropriate for cumulating results, the philosophical position which guided this investigation was that research integration is best considered a form of exploratory rather than confirmatory research.

Accordingly then, the purpose of this study was to generate hypotheses based upon identified differences among the coded variables resulting from this research integration. This effort was limited to the body of research utilizing static iconic visuals in instructional materials. The influence of time of testing, presentation pacing, and subject grade level was examined with respect to instructional effectiveness as measured by cognitive outcomes.

The research literature on perception (Berlyne, 1958; Dember & Earl, 1957; Hershenon, Munsinger, & Keesen, 1965; Vitz, 1966; Wright & Gardner, 1960) and the research literature on instructional media (Bloomer, 1960; Ibison, 1952; MacLean, 1930; Rudisill, 1952) have documented the effects of pictorial complexity on subject preferences. However, there is a fallacy in basing visual design decisions on subject preferences. A number of writers (Bloomer, 1960; Dwyer, 1971, 1978; Lumsdaine, 1963; Otto and Askov, 1968; Travers and Alvarado, 1970) have documented that desired instructional outcomes have not been consistent with expressed preferences for a particular level of pictorial complexity. The research results do suggest that at least three variables (time of testing, presentation pacing, and subject age or grade level) act to produce differential learning in subjects presented with varying degrees of visual complexity.

Time of Testing

Systems for classifying learning tasks abound in the instructional research literature (Gagne, 1977; Dwyer, 1978). Yet the differences among these systems negates the use of any one schema for research integration. Conversely, no other term related to the measurement of cognitive achievement has been defined as consistently across unrelated studies as time of testing. The time lapse between the end of an experimental treatment and achievement measurement tends to be the most stable variable across investigations, although this variable has been defined in terms of minutes or hours by some researchers and in terms of days by others.

Empirical evidence also suggests the inclusion of time of testing as a variable. Peeck (1974) examined illustration effectiveness over time. He found significant differences in achievement favoring illustrated over nonillustrated treatments on delayed retention tests but not on immediate tests. In a related finding, Peng and Levin (1979) found that a superiority for illustrated over nonillustrated treatments remained at a constant magnitude after both immediate and delayed test periods.

Presentation Pacing

According to Dwyer (1978), studies on the effectiveness of different types of illustrations have shown that line drawings have been most effective with external pacing (e.g., experimenter-controlled slide presentations), while with internal pacing (e.g., learner-controlled programmed instruction) realistic photographs were most effective (Hedberg & Clark, 1976). This corroborated the conclusion of Hunter (1943), who found that the time required to learn information in a visual display was, in part, dependent upon the complexity or quantity of information it contained, and of Grover (1974), whose data revealed that the recall of complex stimuli improved significantly as the duration of exposure time increased.

Grade Level

Studies have shown that rapid increases in pictorial learning skills occur from preschool through the elementary years. The difficulty young children have with interpreting pictorial materials has been attributed to inadequate eye movement patterns (Mackworth & Bruner, 1970) and to problems in interpreting dimensional cues and spatial relations (Asso & Wyke, 1970; Brown, 1969). Elkind, Koegler, and Go (1964) have shown that parts of a picture are perceived at an earlier age than are wholes. In a related finding, Piaget and Inhelder (1956) observed that young children reproduced outlines accurately but located details improperly within a drawing. Similarly, Travers (1969) used subjects varying in age from 4 to 12 years and discovered a tendency for young children to latch onto one particular object in a picture when presented with repeated short exposures, while failing to observe other details. Moore and Sasse (1971) used subjects at the 3rd, 7th, and 11th grade levels; they observed differences across these grade levels regarding the amount of picture content the subjects were able to recall.

Several authors have attempted to summarize the many studies dealing with pictorial complexity. Not surprisingly, these attempts have provided a number of different conclusions. A researcher with any particular bias on the issue can find comfort in some particular review. In summarizing his own systematic series of studies of color and realistic detail in still visuals, Dwyer (1978) stated that these variables were differentially effective, depending on the presentation pacing and a number of other factors. Levie (1973) noted that research comparing pictures varying in gross respects (e.g., photographs versus line drawings) had provided no evidence of differences in learning.

METHODOLOGY AND PROCEDURES

Locating Reports of Research

Bibliographic search procedures used to locate pertinent studies in this investigation involved both automated information retrieval and manual searching of selected indices and references known to contain extensive pictorial citations, descriptor terms, and data bases. An initial computer search examined four data bases: Educational Resources Information Center (ERIC), Psychological Abstracts, Sociological Abstracts, and Dissertation Abstracts. As a result of this search, a number of nonproductive descriptor terms were deleted as were the Psychological Abstracts and Sociological Abstracts but several new terms were added for a second search. The second search produced a total pool of 558 potentially relevant citations (378 from ERIC and 180 from Dissertation Abstracts).

The automated search procedures were augmented by a manual search of data-based indices, annual meeting and convention programs, and selected references. The complete indices to *Masters Abstracts*, *Reading Research Quarterly*, and *Social Sciences Citation Index* were reviewed, as were the annual meeting and convention programs for the period 1970-1980 from the following professional organizations: American Educational Research Association, American Psychological Association, Association for Educational Communications and Technology, and the International Reading Association. An unpublished manuscript from Indiana University entitled *Instructional Systems Technology Doctoral Dissertations Completed at Indiana University* (1949-1973) provided additional support

for the automated search of Dissertation Abstracts. Also reviewed were the research abstracts for the first 28 volumes of the *AV Communication Review* and educational volumes of *Communications and Technology Journal*. Finally, extensive pictorial research bibliographies contained in Dwyer (1978), Huggins and Entwisle (1974); Lamberski (1980), Larson and Runden (1950), Levie (1973, 1977), and Norberg (1966) were reviewed for pertinent citations.

Although these search procedures were designed to be exhaustive rather than selective, it was accepted as a limitation of the study that a certain percentage of relevant research reports would escape notice and fail to be included in the initial sample pool. Both titles and abstracts were reviewed when available, including those 558 citations identified by automated retrieval. When titles alone were examined, the procedure was systematized so that the pertinent descriptor terms used in the computer searches also were sought during manual title inspection. The final manual search technique involved the standard bibliographic practice of locating additional citations by reviewing the full text and accompanying references of every research report identified as relevant by title and abstract search. These cumulative procedures continued until no new relevant citations were uncovered, produced a total of 701 studies for the initial sample.

Sample Selection

A three-tiered screening structure was used to pare the sample to its final size. This screening procedure involved the analysis of conceptual and methodological characteristics of the studies. Decisions to include or exclude research reports were made on the basis of information in the report. Report rejection was based on not meeting a single criterion. Thus, once a deficiency on any criterion was noted, the report was rejected.

In order to survive the initial screening, a research report had to satisfy two major criteria. First, the report must have been either experimental or quasi-experimental in nature (Isaac & Michael, 1971). Second, the study must have investigated the effect attributable either to different types of still visual or the addition of iconic to digital content. In applying the latter criterion, it was found that a large number of studies were concerned only with the comparison of digital to iconic information (as in many paired-associate studies); therefore, they were rejected. In fact, this initial screening deleted 424 of the 701 research reports.

The application of the above criteria to the initial pool left 277 research reports for the second screening procedure. The second tier of the screening procedure involved applying the following four criteria to the remaining reports:

1. Studies must have utilized human subjects without physiological, sociological, or psychological abnormalities. An assumption of normality was made for these conditions unless specific information to the contrary was reported.
2. Studies must have utilized treatment illustrations with readily codable attributes, based upon adequate verbal descriptions or upon representative examples.
3. Studies must have used cognitive dependent measures which tested information acquisition.
4. Studies must have incorporated research designs which controlled extraneous variance resulting from differences in illustration content, treatment presentation modes or techniques, illustration iconicity, dependent measures, and subject characteristics.

An additional 73 reports were excluded following this second screening, leaving 204 reports for the final screening activity. The third and final tier of the screening procedure eliminated 52 reports which did not contain quantitative data sufficient for the computation of effect-sizes, estimates of effect-size, or "pseudo" effect-sizes (Glass, 1977). Thus, the initial sample pool of 701 reports was reduced through separate screening procedures to a final sample of 121 data sets based upon 152 reports.

Sample Coding

Research integrations are most credible when variables are defined in ways that are applicable across studies. This guidance translates to avoiding very narrow definitions of study variables in favor of coding categories of a more general nature. Following this advice resulted in a substantial number of studies being included in each coding category. Had this advice not been heeded with respect to illustration coding, a substantial number of additional studies would have been excluded because of inadequate pictorial descriptions. Three major variables of interest to this study (illustration types, time of testing, and grade level) were coded in multiple ways to ensure maximum inclusion of studies despite sparse descriptions. A fourth variable, presentation pacing, was the only variable for which a single coding category was established.

Because different grade levels, illustration types, retention times, and presentation pacing frequently appeared within a single study, individual effect-size comparisons, rather than entire studies were coded. Each effect-size measure within a single study was coded on all coding categories for all variables.

Quantifying and Equating Study Outcomes

The ultimate purpose for conducting the meta-analysis procedures in the present study was to achieve a quantitative aggregation of the findings from various reports of research. To this end, a basic index of achievement effect, called $\underline{d}$ (Cohen, 1977) or effect-size (Glass, 1977) was first calculated for every treatment group comparison.

Glass (1977) has described a variety of measures for calculating $\underline{d}$. Most directly, $\underline{d}$ was computed by first finding the difference between the means of a treated control group receiving only verbal information and a treated experimental group receiving the same verbal information with the addition of an illustration, and then dividing this difference by the control group standard deviation. In the absence of means and standard deviations, Glass (1977) described a variety of measures for calculating or estimating $\underline{d}$ by extrapolating from whatever data the reports did provide.

In the case of reports lacking a control group, it was frequently necessary to compare directly two different experimental groups, using a pooled variance estimate. Through a method of extrapolation (Glass, 1977), values of $\underline{d}$ called pseudo effect-sizes can be established for each of the experimental treatment groups. A number of these pseudo effect-sizes were calculated in the present study and were included in the aggregate data from which comparisons of independent variables were made. All told, 2,607 effect-size values (including 428 pseudo effect-size values) were generated from the available data. The large number of effect-size values from 152 reports of research was a result of the effect-size method of computation; each value was computed while holding constant all other variables at a particular level. Therefore; studies incorporating multiple illustration types,

grade levels, presentation pacing, and retention times yielded multiple effect-size values.

DATA ANALYSIS AND FINDINGS

Data analysis was performed in three distinct stages. The first stage concerned the establishment of the complete data set. The comprehensive data set used in subsequent analyses was an aggregation of both effect-size and pseudo effect-size values. The second stage of the data analysis sought to identify potentially significant main effects and interactions among the numerous levels of the coded variables. The third data analysis stage involved using Tukey's jackknifed method (Mosteller & Tukey, 1968) to obtain mean effect sizes for variables and their interactions identified in stage two of the analysis. The jackknife technique was used to equalize the contribution to the overall mean of studies with vastly unequal numbers of effect-size values.

Stage One of Analysis

A total of 2,607 effect-size values were generated from the available data. The number of effect-size values per study ranged from one to 666 (Dwyer, 1970), with 22 being the mean number of effect-sizes per study. The 2,607 effect-size values represented comparisons among nearly 22,000 treated and untreated subjects from kindergarten through twelfth grade, as well as college students and noncollege adults. Every single grade level from kindergarten through twelfth grade was represented in the sample. The number of subjects per study also varied widely, from a low of 16 to a high of 1,054. The 121 data sets covered a 60-year time span beginning in 1921 although all but 10 of the 121 data sets in the sample were reported in the last two decades. By using the jackknife technique to average the 2,607 effect-size values across all studies and all variables, a grand jackknifed mean effect-size of 0.51 was derived. This value indicates that the post test achievement score of the average subject receiving some form of illustrated treatment was about one-half standard deviation higher than the post test achievement score of the average control group member receiving only the verbal treatment. This jackknifed mean is nearly identical to the grand mean effect-size of 0.5 reported in the Clark and Angert (1981) study. Cohen's (1977) definitions of small ($\underline{d}$ = .2), medium ($\underline{d}$ = .5), and large ($\underline{d}$ = .8) effect-size differences were applied to the analysis of effect-size differences observed in this study. These definitions also were used to derive hypotheses reported in the conclusions.

Stage Two of Analysis

The remaining data analysis steps had as their goal the identification of small, medium, and large effect-size differences among the levels of the coded independent variables. These independent variables included representation realism, chroma, context, embellishment, shading, time of testing, presentation pacing, and grade level. All told, there were 38 coding levels of interest for eight independent variables.

The analysis of main effects and interactions among the 38 levels of eight variables presented too formidable a task to be performed without recourse to powerful statistical techniques. For this reason, multiple regression and frequency analyses procedures were used to pare the number of interactions meriting closer examination to a manageable number.

An a prior decision was made to limit the interactions included in the regression model to two-way interactions due to the conceptual difficulties inherent in interpreting more complex interactions. The total variance accounted for by this model was 29% (F = 18.17 with 2,548 degrees of freedom, p <.0001). Since jackknifed mean differences for all main effects variables were subsequently calculated regardless of regression analysis results, the most important outcome of this regression analysis was the identification of 9 potentially significant (p < .05) interactions. Table 1 presents a summary of interactions which were statistically significant and had at least 10 studies per predictor.

Table 1

Qualifying Interactions Among Illustrations and Context Variables

Chroma X representation realism
Chroma X time of testing
Embellishment X chroma
Embellishment X time of testing
Grade X chroma
Grade X pacing
Grade X time of testing
Pacing X embellishment
Pacing X representation realism

Stage Three of Analysis

Tukey's jackknifing procedure was employed for the final data analysis. Jackknifed means were computed for all levels of all main effects, regardless of regression analysis results, and for all levels of the nine apparent interactions. The results of this analysis have been reported separately for main effects and for interactions.

Iconic coding elements. Table 2 presents a summary of mean effect-sizes for the pictorial characteristics: representation realism, chroma, shading embellishment, and context. All levels of these variables achieved at least a small level of practical significance (d = 0.20), except for illustrations coded as embellished (d = 0.13).

The difference in means of(<>d) or the levels of representation realism proved to have little practical significance (<>d = 0.12), despite the fact that this variable achieved statistical significance in the regression analysis. It was also noted that both photographs and chirographs were coded for levels of shading and chroma. The difference between shaded and nonshaded illustrations was determined to be nearly nonexistent (<>d = 0.01). Yet the d values determined for black and white and for colored illustrated treatments were different (<>d = 0.30). Only chirographic illustrations were coded and analyzed for context and embellishment. Treatments with illustrations presented "in environment" (i.e., with discernible foreground-background relationships) achieved a mean d value twice that of treatments using illustrations "in limbo." The entry embellished drawings was the only category of illustration variable failing to achieve a d value at least equal to a small practical significance level (d = 0.13).

Table 2

Jackknifed Mean Effect-Sizes for Illustration Variables

Coding Element	d	n1	n2
Representation realism			
Chirographic	0.57	114	1,475
Photographic	0.45	48	1,173
Chroma			
Black-and-white	0.40	90	1,608
Color	0.70	50	900
Shading			
Yes	0.51	71	1,832
No	0.52	72	717
Embellishment			
Yes	0.13	45	187
No	0.66	48	1,173
Context			
Limbo	0.28	21	186
Environment	0.56	71	2,074

n1= Number of Studies

n2= Number of effect-size values.

This finding implies that, with respect to mean cognitive achievement, treatments using embellished drawings were not any more effective than verbal-only control treatments. Conversely, treatments with unembellished drawings (d = 0.66) were much more effective than either treatments with embellished drawings (d = 0.18) or verbal-only control treatments.

Table 3

Jackknifed Mean Effect-Sizes for Time of Testing, Pacing

Time of Testing	d	n1a	n2b
Immediate	0.51	114	1,846
Delayed	0.55	37	725
One week or less	0.15	16	52
More than one week	0.59	21	673
Pacing			
Internal	0.20	53	1,108
External	0.76	71	1,499

Although both immediate and delayed test d values reached medium levels of practical significance, a small difference (<>d = .04) was found between immediate and delayed testing. A closer examination of delayed testing, moreover, showed that the medium practical significance level for delayed testing was more likely attributable to the mean for data sets with greater retention test periods. In fact, the difference between retention test levels (<>d = 0.44) approached a medium level of practical significance, indicating that the effectiveness of illustrated treatments actually increased significantly as the time of administration of post-treatment criterion measures went beyond one week.

Presentation pacing. Illustrated treatments were coded for either internal or external pacing. As shown in Table 3 the d value for internally-paced presentations did reach the small practical significance level (0.20), whereas externally-paced illustrated treatments nearly reached a large d value (0.76). The difference in effect-size value between the two pacing formats reached a medium practical significance level (<>d = 0.56).

Grade level. Data not reported in Table 3 showed a progressive increase in illustration effectiveness as measured by d from kindergarten through grade 12, with a marked drop-off in the size of d at the adult (college and noncollege)levels.

Interactions

Jackknifed means were calculated on nine potential interactions identified by previous analyses. An inspection of the mean differences among the cells of three possible interactions (embellishment by time of testing, embellishment by chroma, and chroma by time of testing) revealed the interacting jackknifed means were not sufficiently different from the

main effects means to warrant further analysis. Thus, six interactions meriting closer examination are reported in tables 4 and 5.

Grade level by time of testing. The results of this analysis are reported in Table 4. The negative d value (-.33) found during delayed testing with college and noncollege adult learners was the only cell in all the reported values where illustrated treatments were less effective than verbal-only control treatments. It is apparent this value contributed to the disordinal interaction between the K-6 and 14-15 (college to non-college) grade levels with time of testing.

Table 4

Jackknifed Mean Effect-Size Interactions For Grade by Time of Testing, Pacing and Chroma

Grade Level	Immediate Testing			Delayed Testing		
	d	n1	n2	d	n1	n2
K - 6	0.27	46	270	0.20	15	52
7 - 12	0.89	24	630	0.89	10	463
14 - 15	0.38	49	898	-0.33	12	210
Level	**External Pacing**			**Internal Pacing**		
	d	n1	n2	d	n1	n2
K - 6	0.22	27	165	0.35	24	193
7 - 12	1.13	14	785	0.36	12	308
14 - 15	0.50	32	501	0.03	21	607
Grade Level	**Color**			**Black-and-White**		
	d	n1	n2	d	n1	n2
K - 6	0.31	21	126	0.28	34	217
7 - 12	0.90	12	514	0.90	16	547
14 - 15	0.59	16	236	0.12	44	820

n1 = Number of data sets n2 = Number of effect-size values

Grade level by pacing. Table 4 reveals that externally paced illustrations were more effective at both the 7-12 and college through noncollege adult levels than were internally paced illustrations. Interactions, however, were evident when the K-6 grade level was compared

with either the 7-12 or 14-15 levels since internally paced treatments were more effective than externally paced treatments at the lower grade levels.

Grade level by chroma. Only at the college and noncollege adult level (14-15) did a substantial difference in means occur for colored versus black and white illustrations with the color treatment being more effective. This phenomenon was responsible for the disordinal interaction between the K-6 and 14-15 grade levels with chroma. Similar to the preceding interactions, these data are provided in Table 4.

Table 5

Jackknifed Mean Effect-Size Interactions for Representation Realism by Chroma, Pacing, and for Pacing by Embellishment

Type of Representation	Color			Black-and-White		
	d	n1	n2	d	n1	n2
Chirograph	1.00	37	380	0.42	82	999
Photograph	0.54	24	400	0.37	35	609
Type of representation	**External Pacing**			**Internal Pacing**		
	d	n1	n2	d	n1	n2
Chirograph	0.90	65	818	0.18	51	657
Photograph	0.61	35	621	0.21	15	391
Pacing	**Embellished**			**Not embellished**		
	d	n1	n2	d	n1	n2
External	0.03	22	83	1.03	30	695
Internal	0.18	23	104	0.13	20	478

n1= Number of data sets. n2= Number of effect-size values

Representation realism by chroma. The results of this analysis provided in Table 5 suggested that color contributed more significantly to illustration effectiveness when representations were chirographic than when they were photographic. Moreover, black and white representations were nearly equally effective as either photographs or chirographs, yielding an ordinal interaction with the 0.46 difference between the means of colored chirographic and photographic representations being responsible for the interactions.

Representation realism by pacing. The results of this analysis, suggested that the mode of representation realism was a significant factor in illustration effectiveness only under conditions of external treatment pacing. These data indicate the disordinal interaction evident by comparing the means in Table 5 largely due to the magnitude of the effect size difference occurring for external pacing.

Pacing by embellishment. Although this interaction was not included in previous regression analyses, the jackknifed mean main effects results suggested the need to investigate possible interactions involving embellishment. Based on an inspection of jackknifed means, all other interactions involving embellishment were eliminated from further consideration. The possibility of a disordinal interaction, however, between pacing and embellishment was substantiated by the results shown in Table 5. Whereas all other cell means indicated no practical difference between illustrated and nonillustrated treatments when classified by pacing and embellishment, the cell for nonembellished and externally paced drawings achieved a mean d (1.03) that considerably exceeded a large significance level.

DISCUSSION

Iconic Coding Elements. The results of the main effects analysis highlighted the difficulty of drawing definitive conclusions regarding the relative merits of realism or relevant cues. Support for high realism was substantiated by the small significant difference between pictures in "environment" versus pictures in "limbo," in favor of the former context condition. Apparent substantiation for high realism also was provided by the medium significant effect-size difference favoring unembellished over embellished drawings, although this support was not conclusive due to the possible alternate uses of embellishment. If embellishment was used consistently as a cueing technique, the present results would have run counter to those proposed by Attneave (1954). In accord with principles from information theory, Attneave hypothesized that learning effectiveness would be increased by caricatures. He reasoned that boundaries or contours were primary information carriers in illustrations and that information critical for recognition was concentrated where contours changed direction most rapidly. The use of caricatures increased learning efficiency by exaggerating those points where contours changed the most.

A small effect-size difference was found favoring chirographs over photographs when all other variables were held constant. This difference, however, increased to practical significance when treatments were externally paced and increased more when both chirographs and photographs were colored. These findings confirm the results of a previous meta-analysis (Clark & Angert, 1981), in which the most effective illustrated treatment used color chirographs when treatments were externally paced. The relevant cue theories would appear to be bolstered by this particular coding element comparison.

Time of Testing. Common experience probably would suggest to many people that, memory being imperfect, cognitive achievement scores would decline as retention measurement is further and further removed in time from the initial information presentation. The results of this and previous studies would appear to run counter to common experience when illustrations complement the verbal material. As the results of this study

indicated, pictorial effectiveness was essentially unchanged between immediate and delayed testing, except when immediate testing was compared to delayed testing at periods later than one week following presentation. This result is not uncommon in pictorial research. Peng and Levin (1979) found that the magnitude of difference favoring illustrated treatment groups over controls was unchanged after three days. Peeck (1974) also found significant differences in achievement between illustrated and nonillustrated treatment groups after testing at both one-day and one-week intervals. These differences were not found on immediate testing. Conceivably, unessential pictorial details could be filtered out during perception; subsequent retention and recall might be based on a more efficient skeletal reconstruction of essential features (e.g., borders, edges).

Presentation Pacing. The method of treatment pacing does make a significant difference in pictorial effectiveness. In general, illustrations were a more effective complement to verbal material when subjects could not control the exposure time. The results for the pacing variable were nearly identical to those noted in Clark and Angert (1981). However, these results may be illustrative of the confusion between symbol systems and sensory modes (Conway, 1967), which has plagued media research interpretation. Since most externally paced presentations presented digital symbols auditorially rather than visually, these results may say as much about the distinctions that exist between verbal listening skills and verbal reading skills as they do about illustration effectiveness or pacing differences.

Grade Level. When grade level sample sizes were enlarged by Grouped-Grade coding, trends became more evident. On the surface, these trends appeared to support the concept of a curvilinear continuum of picture effectiveness with increasing age (Hutt & McGraw, 1969). Peak picture effectiveness occurred at the 7-12 grade levels with lower levels of picture effectiveness at the K-6 and college/noncollege adult levels. Myatt (1975), Rankin and Culhane (1970), Travers and Alvarado (1970), and Wubbena (1977) all probably would attribute increasing pictorial effectiveness from K-12 to a progressive rise in pictorial interpretive abilities associated with maturation. This explanation, however, is not sufficient to account for the sudden decline in effectiveness beyond the twelfth-grade level.

Figuratively attempting to explain this curvilinear pictorial effectiveness continuum in terms of visual literacy skills may be incorrect. It may be more useful to examine this continuum phenomenon in terms of increasing verbal skills. Since college level students are normally selected in large part on superior verbal abilities, college level subjects in illustration experiments may tend to rely on this strength regardless of whether they are assigned to illustrated or nonillustrated treatment groups.

CONCLUSIONS

Although Glass (1976) considered meta-analysis to be a particularly useful technique for resolving conflicting research findings, the utility of meta-analysis was interpreted more conservatively in the present investigation. Thus, the purpose of the present study was to cumulate past research results for the purpose of establishing an alternative data base from which new research efforts could be initiated. To this end, hypotheses for future research were derived. The hypotheses which follow are only a representative sample of all potential hypotheses.

Experimental treatments with any one of the following characteristics or combination of characteristics, when compared with nonillustrated control treatments, will be more effective, at a d value of 0.80 or greater:

1. Treatments using illustrations at the 7-12 grade levels.
2. Treatments using illustrations at the 7-12 grade levels under conditions of either immediate or delayed testing.
3. Externally paced illustrated treatments at the 7-12 grade levels.
4. Treatments using either black and white or color illustrations at the 7-12 grade levels.
5. Externally paced treatments using chirographs.
6. Treatments using color chirographs.
7. Externally paced treatments using nonembellished illustrations.

While these hypotheses were derived from the effects of the variables explored in this study, it is expected that future researchers will incorporate new variables in their studies and thus will define more precisely the parameters under which these hypotheses may be sustained or rejected.

Moreover, the reader is reminded that these hypotheses were based on average values derived from multiple studies; as such, some variance about the means is to be expected. The true measure of the value of these hypotheses will not be the specific values derived in future individual studies, but whether these hypotheses are sustained or rejected after the results of repeated studies are cumulated. The breadth of these hypotheses merely provides a datum plane from which future efforts may grow. It indicates the great amount of research which still remains to be accomplished.

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INFORMATION MANAGEMENT IN OUR SCHOOLS: A TIME FOR CHANGE

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The potential for using classroom microcomputers to facilitate research on teaching and learning has, thus far, been relatively unexplored. This paper discusses ways that the present and developing capabilities of microcomputers can be used to enhance teaching as a profession and also points to some changes that will need to occur in order to fully realize this potential.

The rapid influx of microcomputer technology in the field of education has been well documented (Becker, 1984; Ingersoll & Smith, 1984), as has the numerous and varied recommendations for educational reform (Passow, 1984). These concurrent developments have spawned a great deal of discussion concerning how computers can be used to increase educational effectiveness. While most decision makers in education seem to view the computer only as a vehicle for the delivery of instruction, the vast majority of microcomputers in the United States are being used for information management.

The potential for this relatively unexplored application of technology in the field of education appears to be both real and exciting, not only in terms of what can be done to assist the classroom teacher, but also to further research and theory building in education. To understand not only the potential but also the need for this type of application of microcomputers requires an understanding of how information is currently managed within educational systems.

PRESSURES + TECHNOLOGY = THEORY DEVELOPMENT

Information can be defined as knowledge obtained from investigation, study or instruction (Woolf, 1974). Information management then, involves the gathering, storing and manipulating of this knowledge. Information management systems in schools in the mid 80's appear to have developed from the interaction of three basic elements: (a) pressures, both internal and external, exerted on the school system for certain types of information; (b) the availability of information management technology to facilitate the handling of this information; and (c) an understanding on the part of school administrators of information management theory as it applies to the school environment.

Pressures for information have most often been exerted on schools externally. For example, when federal and state agencies began providing large amounts of funding to schools, they also began exerting pressure for certain types and amounts of information (Armstrong, Henson & Savage, 1985). Typically, the primary information requested was average daily attendance figures.

Similarly, pressure was exerted by various factions for information concerning student grades. Yet another form of pressure that directly affected the school system was economic in nature. Most school districts have always operated under stringent budget restraints, so cost effective

means always had to be found to relieve any pressure on the system for detailed information.

In the late 60's, when school administrators first began searching for means to alleviate pressures for information, computer-based information management technology was in its infancy. Computers were relatively new and very expensive. Appropriate software was just being developed, and its use required programming skills rarely available in schools. As a result few school personnel understood the potential computer technology held for resolving their information management needs. Added to this lack of information was the phenomenon that long range planning had seldom been an integral part of school management systems. Most information management systems in schools tended to develop ad hoc, over time, not as a result of careful analysis and planning.

The practical means for relieving these pressures for information, then, has been to use available resources to accomplish the task. By utilizing existing personnel, namely teachers and secretarial staff, at different levels within the school system to gather, store and manipulate information, a system evolved that remains basically unchanged to this day. At the first level, teachers collect, manipulate and store large amounts of data such as class attendance and grades. They are required to pass this information, by hand, to building level staff. Data are typically summarized at the building level and then passed to district-level personnel for final organizing, storing and manipulation.

For many years this system has proven to be a relatively acceptable solution to most schools' information management needs. As long as the information required to be analyzed, processed, and disseminated was not detailed or voluminous, timelines for storage and retrieval remained flexible, and the teacher's time could be acquired at costs significantly less than other options, this system remained unchanged. These conditions can no longer be assumed. Current systems no longer are capable of meeting minimum requirements for educational information in a cost effective manner.

NEW PRESSURES, BETTER TECHNOLOGY, OUTDATED PRACTICES

The types of pressures being exerted on schools and the availability of computer technology continue to change. The push for school reform in many states, for instance, has been placed high on political and legislative agendas which, in turn, have brought a great deal of external pressure to bear on the educational systems (Honig, 1985). Emphases placed on efficiency, productivity, and accountability have resulted in increased attention to academic time, testing, mandated curricula, and teacher competencies. These emphases have dramatically increased the information management load that needs to be carried by the school. Many states now require schools to show a direct relationship between daily instruction, student evaluation and a state mandated curriculum. Obviously the source for almost all of this information is the classroom.

Yet few changes have occurred in the structure of information management systems in schools. This assertion is reflected in the observation that while schools have obtained microcomputers in large numbers in recent years, most machines are being used in an instructional capacity rather than as information management devices (Becker 1984). While the cost of people(salaries, benefits, etc.) has risen 6% per year, the cost of computing has dropped at a rate of about 25% per year, but school

administrators still seem to perceive just the opposite to be true (Lipson, 1986). Thus while the pressures on schools for information have greatly increased, as has the availability of the technology, a corresponding change in attitude has not occurred on the part of school administrators. The practice of school information management, or at least administrators' understanding of it, remains basically the same - have the teacher bear most of the load. However teachers do not have the time, nor does an assignment of duties of this type capitalize on their years of professional training and development. To be able to function as truly professional educators, teachers must be provided with both resources and time to effectively utilize their skills.

THE POTENTIAL FOR CHANGE - A SCENARIO

Don Washington is a high school mathematics teacher. The last bell of the day has rung, and Don is rushing to catch his carpool. Before leaving campus, he stops in the teachers' lounge to check his mailbox and pick up his report sheets. Since Don isn't driving this week, he'll have time to review the day's analyses on the way home.

In the car while settling back for the ride, Don checks the top of the first computer sheet and recognizes the familiar readouts - his name, classroom and section numbers, and today's date. He makes mental note of the fact that twelve class days remain until the next grade reports are due, and that the school year is almost two thirds over - 119 down, 61 to go.

The next report on the sheet lists the daily attendance figures. Don, like most teachers, doesn't need a form each day to tell him who was absent or tardy, but this report goes far beyond these basic facts. Once Don spends the ten seconds taking attendance each period via his classroom microcomputer, each student absence is immediately checked through the attendance clerk. If excused, the printout reflects it, if not, the student's parent or guardian is contacted by office personnel to determine the cause. Student tardies and absences are cumulatively totaled and automatically analyzed for patterns. A copy of Don's lesson plan and assignments for each student that missed a class are printed out next. This allows him to make any necessary corrections before they are automatically sent to student distribution first thing in the morning. Most of his students will receive and be able to begin catching up on the work they missed before they actually return to the next class meeting. In this way, absences no longer cause Don a great deal of extra work, nor do they greatly impede a student's progress.

Further down the report, Don finds statistics on the progress evaluation he administered in his fifth period algebra class. At Don's school these evaluations are now standardized and normed for the district. All items are tied directly to the state mandated curriculum objectives, the mastery of which forms the minimum competencies for all accredited courses. On most progress evaluations students complete a machine-scored answer sheet which is immediately scanned by a device networked to the school's main computer. This allows three things to happen: the school computer, not the teacher, manages the vast majority of the student records that have to be reported at regular intervals; each student receives immediate feedback on his or her performance; and Don receives a copy of the fully analyzed results that same day.

The printout not only reports each student's success or failure with each objective, but also displays the results of an error pattern analysis on each student's work. This type of an analysis can often diagnose weaknesses and at the same time suggest means for remediating problem areas.

Today's evaluation, for example, covered rational equations. One of Don's students who failed to achieve a couple of the objectives is diagnosed as having a consistent problem with the algorithm for adding fractions. Don can now spend a relatively short amount of time with this student and help her achieve mastery of these objectives. Another student who has failed to satisfy most of the objectives shows no consistent patterns to his errors. All of his mistakes are apparently of a random nature. This may signify any number of things, but the main issue here is that this student will need more individualized instruction than Don can afford to give during class time. He will assign the student to a tutoring session and be advised of his attendance and progress.

Class totals for this evaluation reflect how Don's students have done compared to other students taking the same course this year and in the past. Don readily admits to having been rather unsettled by this portion of his printouts. Number one, he worried about this information being used to play teacher against teacher for merit pay and career ladder decisions, but his principal soon put the entire faculty at ease on this point. He assured everyone that this information was for individual teacher's use only, and no results would ever be used for promotion or salary increases. Number two, the statistics themselves were rather intimidating, even to Don who is a math teacher (imagine how some of the other faculty members reacted). This anxiety was eased though, through the patient guidance of the school's counselors and evaluation specialists. Soon Don began to understand the significance of means, modes, z-scores, and standard deviations.

The final page of the printout contains the next day's calendar. Don's proposed lesson plans for each period are listed along with any special activities scheduled for the students and faculty. Important reminders for the rest of the month are included along with a list of recent additions to the faculty reading room. The final announcement lists all of the faculty, staff, and students who have birthdays tomorrow.

By the time he arrives home, Don has most of his day's work reviewed, and he already knows what specifically needs to be prepared for tomorrow. But Don's school computer still hasn't retired for the day. Don recently purchased a modem for his family's microcomputer, so he is now able to communicate with the school computer from home and can easily update tomorrow's lesson plans in plenty of time. This also affords him the opportunity to accomplish some things he never quite seems to have the time for at school. For example, he will probably access some of his students' permanent records tonight in an attempt to investigate some possible causes for problem areas he has recently discovered. If he becomes puzzled with an unusual situation, he will ask the computer to analyze the data and recommend possible solutions. For instance, last semester Don had a student who consistently did poorly on examinations, but usually turned in quality homework. Don's first reaction was to suspect the young man of copying his assignments from another student, but he refrained from condemning the student without better cause. Despite his initial apprehensions to do so, Don consulted the computer. He found that by simply entering the basic facts concerning the problem - student ID, good homework, poor examinations, types of tests administered, testing conditions, etc. - Don was able to get a list of possible means for resolving the problem. Each option contained reading references for further study and a list of people within the school district or community who could be contacted for assistance. In this situation Don's first choice was test anxiety which was rather obvious, but in the process he learned a great deal about recent research in the area, and with the help of the district's educational

psychologist, was able to greatly improve the student's performance. Don became a believer. Not that the computer had all the answers, but that it could quickly and easily provide some helpful information he needed to make informed decisions concerning the many and varied problems he uncovered in the classroom. It also assisted him in developing solid, professional relationships with the many talented educators within and around his school community. Don's student is now performing much better on evaluations as evidenced by his name appearing on a recent printout of the school's last honor roll.

By the way, Don is not a typist, but he has learned to hunt and peck his way around the keyboard. He could enter as much of his own data as he wanted, but he lets the data entry specialist at school handle most of the big work for him. After all, the computer is supposed to help him do his job better, not make more work for him, right?

Don and his school computer are working together in other ways too. In conjunction with the local state university, Don's school is compiling and analyzing all the cumulative classroom data they collect, using real classroom experiences to expand the dimensions of research on teaching and learning. A new elementary reading program, for instance, that has just gained district wide acceptance and praise, was developed and slowly integrated into the curriculum over a five year period. During the implementation period a great deal of unobtrusive research was conducted. The district can now feel confident that the program will be effective with their students.

THE CHALLENGE FOR EDUCATION AND TECHNOLOGY

Believe it or not, this scenario is possible and is not far from becoming a reality. Every day, research is assisting educators to make better decisions concerning the critical variables associated with effective instruction. Further, microcomputer technology has made almost unbelievable advances in the past five years. The necessary computing power for this scenario to become reality is already present in many of our schools. Two critical areas, however, need to be attended to before Don's full experience can be shared by all teachers.

The first is in computer science. Database management software has already been developed that can organize the large amounts of information necessary for a classroom application similar to the one portrayed above, but storage accomplishes only half the task. Data are meaningless unless a user can easily access the information and readily determine important relationships that may exist between and among that information. A truly relational database needs to be developed that is capable of maintaining a dynamic rather than static association between separate elements of the system. At the same time, an interface to all the information must allow the user selective access to these relationships. What this means for education is that the system must be capable of determining cause and effect relationships between variables of instruction and be able to prompt a teacher to take advantage of all the information available on any given topic. For example, if a teacher is entering a lesson plan for a two week unit of instruction, the computer system should be capable of analyzing previous semesters' data along with present student profiles to determine for the teacher whether two weeks is an optimal amount of time for the unit. If, for instance, the teacher's students have scored consistently poorly on past evaluations of this unit, more time, other resources, and/or different modes of instruction may be necessary. While teachers maintain these types of

mental notes from year to year, often these analyses are overlooked or not recalled during the planning phase of instruction.

Current research by computer scientists in the area of expert systems holds a great deal of promise for this type of application, but state of the art technology has historically taken longer to reach education than most other fields. Ties need to be established now that will integrate the needs of education with the development of the technology.

The second area where change needs to occur is within the school system itself. School administrators need to analyze their perceptions of both how information can best be managed within the school environment and the nature of the teacher's role with respect to that system. They need to understand the present and developing capabilities of microcomputer technology, and how the role of the teacher can be greatly enhanced if they are assisted by a school's information management function rather than burdened by it. You cannot use a new technology effectively within an organization that evolved or was designed for a very different, older technology (Lipson, 1986).

CONCLUSION

The times are rapidly changing due in no small part to an explosion in the area of information technology. If schools, as we know them, are to survive, they must begin undergoing a corresponding change in structure and philosophy. The amount of new information being produced is said to be doubling every five years. At this rate and given the unchanging nature of school information management systems, it may not be long before parents begin opting for other means of educating their children. The time for change is now.

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A SYSTEMATIC APPROACH TO THE DEVELOPMENT OF CAMPUS LEVEL ADMINISTRATIVE INFORMATION MANAGEMENT SYSTEMS

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INTRODUCTION

The provision of computer support for information processing activities of campus level administrators is necessary to increase their efficiency and effectiveness. The facilitation of data consolidation and reporting to the school's district office can produce significant improvement in an administrator's ability to manage campus level operations.

The school administrator's primary task is to manage school resources so that maximum educational benefits can be provided to students (Saxe, 1980; Stoops, Rafferty, & Johnson, 1981). Having the ability to screen out nonrelevant data and focus on relevant information helps administrators make correct decisions and set appropriate short term goals that increase the effectiveness and efficiency of the school (Bolton, 1980). Not having immediate access to information when it is needed is a major factor limiting the effectiveness of school administrators (Kenny & Rentz, 1970).

The amount of data maintained and manipulated by school administrators is increasing in response to a growing need for the information required to make decisions and to produce necessary reports. Manipulation, rather than the interpretation and use of data, is requiring an increasing portion of administrators time and budgets (Crawford, 1985). Due to the large quantities of data that school administrators are required to maintain, a significant amount of administrative time is spent performing routine clerical and accounting duties rather than performing the activities perceived as important by school clients (Bolton, 1980). These factors have fostered the search for new technologies which provide a mechanism that will free administrators to pursue those tasks requiring their professional training and abilities.

Many school administrators assume that the use of computers to automate repetitive and time consuming activities will improve their use of time and enhance their ability to make decisions (Keher & Schepis, 1982). This assumption increasingly has led administrators to adopt computers for information management. To illustrate, in 1985, ninety two percent of Texas public school districts with an average daily attendance of more than 500 students were using computer systems to support selected information management activities of district-level administrators (Texas Education Agency, 1985).

Information management support at the campus level of public school districts has become economically possible only recently. This is due to the declining costs of 16-bit microcomputers capable of storing and processing vast quantities of data and the development of powerful data management software. These factors have provided the technology base necessary for an affordable information management system for campus level administrators (Bybee, 1982; Jones & Duke, 1983; Moscow, Bolton, & Young, 1982; Weintraub, 1985). The increasing adoption of computer technology as a tool for the support of administrative information management in public schools

has increased the need for systematic practices for developing, implementing and evaluating an administrative information management system (Lindelow, 1984; McIsaac, 1984a, 1984b).

Structured systems analysis procedures have been used in the development, implementation, and evaluation of automated information management systems in business settings for more than a decade (Edwards, 1985). Systems analysis practices, as applied to the automation of business, are an outgrowth of the fields of cybernetics (Weiner, 1948) and operations research (Ackoff, 1964), both of which are based on general systems theory developed in the 1930's by Ludwig Von Bertalanffy (1968). It would appear that systems analysis tools, developed for business, could serve a similar role in the development, implementation and evaluation of an integrated information management system for campus level school administrators.

Though not widely applied, the use of general systems theory and systems analysis procedures for developing, implementing and evaluating information management systems in administrative public school settings has been suggested by several authors (Kiser, 1984; Lindelow, 1984; McIsaac, 1984a, 1984b; McManama, 1971; Montello & Wimberly, 1975; Thomas, 1971). Suggested procedures include a formative analysis of the organization's current information management system as a means of identifying areas that are suitable for automation and the evaluation of the automated information management system once it is implemented to ensure that it continues to meet its intended purpose (Bybee, 1982; Florida State Dept. of Education, 1983; McIsaac, 1984a, 1984b).

Evaluation procedures that yield qualitative and quantitative measures of the efficiency and effectiveness of an information management system are encouraged (Hodge, Fleck, & Honess, 1984). Unfortunately, evaluations of many of the microcomputer based information management systems in both business and educational settings have suffered from a similar problem; little quantitative information has been collected to support the assumption that an automated information management system increases productivity (Brown, 1983).

The following discussion provides an example of how systems theory and systems analysis methodology can be used to develop, implement and evaluate administrative information management systems in public schools. The systems development cycle is used in this discussion as the basis for sequencing the activities necessary for the development, implementation and evaluation of an information management system. The systems development cycle (Bennett, 1971; Hodge, Fleck, & Honess, 1984) is composed of five stages; (a) Systems Planning, (b) Systems Analysis, (c) Systems Design and Development, (d) Systems Implementation, and (e) Systems Evaluation. The completion of each cycle of five stages would automate one functional area of a school's total administrative information management system (e.g., attendance, discipline reporting, ect.) and produce information needed to determine the value of an implementation.

APPLICATION OF SYSTEMS ANALYSIS TECHNIQUES

Systems planning, the first stage of the structured systems development cycle, involves a preliminary analysis of the existing information management procedures used in the school and the identification of the functional areas that most need improvement. Information identifying the formal channels of data flow within the school district is collected through the study of school documents and interviews with administrative personnel. Data flows are represented through the use of Yourdon data flow diagrams

(DeMarco, 1979; Dickinson, 1980). Cost estimates are developed from current budgets and interviews with school personnel responsible for finances. Cost-benefit ratios are developed based on projected hardware, software and training costs, compared with any projected dollar savings in user time. Cost estimates are amortized over the projected life of the system. Benefits are defined to be the dollar difference between the cost of the present system and the automation. Cost and benefit estimates at this stage of the analysis are rough estimates, (+ or - 50%) (Dickinson, 1980), and are used to prioritize the functional areas suitable for automation. This stage involves nine sequential activities (Table 1). It is important that the objectives of the information management system be linked to the goals of the organization.

Table 1

Systems Planning

	DESCRIPTION	METHODOLOGY
1.	Identify context-level data flows of the school	Interview central administrators and study school documents
2.	Develop context-level data flow diagram of the current IMS of the district	Interview central administrators and study school documents
3.	Identify campus-level data flows and variation by grade level	Interview campus-level administrators and study campus documents
4.	Identify IMS problem areas	Interviews with campus administrators
5.	Develop level 0 data-flow diagram of current campus IMS	Interview campus-level administrators and study campus documents
6.	Preliminary estimation of costs for each of the functional areas having problem areas	Interview central administrators and study campus documents
7.	Specify objectives for new system for each functional area having trouble	Review decision process of the central administration
8.	Make preliminary estimation of costs for development and implementation of each new system and the value of the benefits that will be gained by the accomplishments of the stated objectives	Interviews with school administrators
9.	Select the functional area for further analysis, systems development implementation, and evaluation	Rank order function by the central administration of the school, the highest ranked function is selected for automation

Systems analysis, the second stage of the structured systems development cycle, involves the formal documentation of existing information management procedures, followed by a diagnosis of necessary changes for accomplishing the objectives of the new system. An open ended instrument is administered to campus level administrators to identify the

processes, associated tasks and personnel involved in completing the selected administrative function. This information is used to develop and validate a formal instrument for the measurement of the amount of campus level administrative staff time that is required for the completion of

Table 2

Systems Analysis

	DESCRIPTION	METHODOLOGY
1.	Administer an open ended instrument which will identify the processes, component tasks and personnel involved in the performance of the functional activities	Administer to building principals and staff
2.	Develop level 1 data flow diagram and data dictionary of the processes of the function	Data flow diagrams based on open ended instrument, dictionary on the study of campus documents
3.	Develop, validate and administer a formal instrument used to determine the amount of administrator/staff time required for completion of the processes and tasks which make up the function	Develop the instrument based on the open ended instrument in step one, validate by with review school administrators, administer to campus level administrators
4.	Calculate time and cost figures for the processes and tasks of the function	Multiply the identified time requirements with average value figures for administrator and staff time
5.	Identify the current manual/automated system boundary	Interview administrators
6.	Develop, validate and administer an instrument to measure the subjective aspects of the value of the current system	The instrument will be administered to campus administrators
7.	Diagnose changes in the current system necessary to produce a new system which addresses the identified problems and system objectives	Management decision of the central administration based on an analysis of the information from the previous steps
8.	Develop level 1 data flow diagrams and data dictionary for the proposed system	Based on decisions in step eight and data flow diagrams from step two
9.	Identify the manual and automated system boundaries for the proposed system	Management decision of the central administration
10.	Adjust estimates of costs and benefits that will result from the implementation of the proposed system	Based on interviews with school administrators and estimates of systems development and implementation costs
11.	Approve systems development activities for the proposed new system	Management decision of the central administration

particular functions. A second instrument is developed and validated which seeks to measure the estimated value of the current information management system. This instrument is administered to campus-level administrative staff and responses, where appropriate, are quantified utilizing a five point modified Likert scale (King & Epstine, 1983). Important qualitative questions are presented in an open ended format as part of this instrument. An analysis of information collected from these instruments enables adjustment of the current system permitting objectives for the new system to be achieved. Refinements are then made in the cost and benefit estimates for the selected function to enhance their accuracy (+ or - 20%) (Dickinson, 1980).

Systems design and development, the third stage of the structured systems development cycle, is accomplished in nine sequential steps (Table 3). The procedure involves the detailed documentation of the new system, using Yourdon data flow models and an associated data dictionary, based on the results of the systems analysis phase. The use of relational database

Table 3

Systems Design and Development

	DESCRIPTION	METHODOLOGY
1.	Develop detailed data-flow diagrams and data dictionary for the new system	Interviews with administrators and study of documents
2.	Develop E-R model	Based on data flows and data dictionaries as well as interviews with school administrators
3.	Specify hardware and software requirements of the new system based on the technical requirements of the new system	Analysis of data transfer loads and available hardware and software specifications
4.	Write, test, debug, and document any necessary software	Programming activity
5.	Perform an acceptance test of the new system at the pilot campus	Implement the new system in a selected pilot site campus
6.	Modify the new system as necessary to pass acceptance test	Programming activity to meet user needs and suggested improvement
7.	Adjust estimates of costs and benefits that will result from implementation of the new system	Adjustment based on previous activities
8.	Refine the system documentation of the new system	Analysis of user needs in the pilot implementation, update system documentation to reflect changes from step six
9.	Approve implementation of the new system	Management decision by the central administration

technology for developing an information management system is recommended, based on the need for an integrated approach to organizational information management (Hodge, Fleck, & Honess, 1984). Entity-Relationship models are developed to facilitate the implementation of a database approach to software development (Goldstein, 1985), provided database technology is determined to be an appropriate tool.

These steps are followed by the development of systems software and hardware specifications based on the technical requirements of the projected information management system and the coding of any necessary applications software. Refinements are then made in the cost and benefit estimates for the selected function based on the new information collected so that their accuracy is plus or minus five percent (Dickinson, 1980).

Systems implementation, the fourth stage of the structured systems development cycle, involves the conversion from the current to the new system. It involves the training of system users and the development of systems support and maintenance procedures. Completion of this stage involves five sequential steps (Table 4). A small subset of campuses are selected to serve as pilot sites for automation by the school's central administration. A matching subset of campuses that correspond to the grade level of the campuses selected for automation is also selected by the school's central administration to serve as a control group for the evaluation of the new system.

Table 4

Systems Implementation

	DESCRIPTION	METHODOLOGY
1.	Select campuses to use the automated system	Management activity of the schools central administration
2.	Train selected users in the operation of the new system	Training activity
3.	Install the new system at the selected campus administrative offices	Physical installation of hardware and software
4.	Transitionary period for users to explore the use of the system	Supervision of initial system use
5.	Conversion completion	Require use of the system in selected schools

Systems Evaluation, the fifth and last stage of the structured systems development cycle, involves the analysis of the new system in relation to the existing system and the stated objectives of the new system. Completion of this stage involves five sequential steps (Table 5).

The evaluation utilizes a pretest-posttest control-group design (Borg & Gall, 1983). One group is using the new system and the comparison group continues to use the old information management system. The results of the pre-implementation and post-implementation evaluation scores of the old and new systems of the two groups are compared to determine if a significant change in the evaluation score occurs. If the assumptions of an ANCOVA procedure can be satisfied, an analysis of covariance is performed on the means of the posttest scores with the means of the pretest scores as the

covariate. Otherwise, an analysis of variance test is performed between the posttest scores of the two groups (Borg & Gall, 1983). A final cost-benefit ratio is computed for the automation utilizing data gathered on actual time savings resulting from the new system. The qualitative benefits of the automation that cannot be quantified are measured through the use of open ended questions. The qualitative responses are then compiled, combined with the cost-benefit data and reported in an evaluation document submitted to the school's central administration. The central administration uses this information to determine if the new system is successful and its use should be extended to other district campuses or if it requires further refinement. If it is determined that refinement is required, problem areas are identified and the five stages of the system development process are repeated. If the new system is successful the process is repeated for the next functional area prioritized for automation.

Table 5

Systems Evaluation

	DESCRIPTION	METHODOLOGY
1.	Administer the previously developed instrument for measurement of the subjective aspects of the value of the system	Administer to users of automated system and the comparison group using the manual system
2.	Administer the previously developed instrument for measurement of the time required for completion of the processes and tasks of the function	Administer to users of automated system and the comparison group using the manual system
3.	Compare the pre and post evaluation scores for each group	Perform statistical analysis of the data for each group
4.	Develop a cost benefit ratio for the system	Compute from cost data and time savings benefits
5.	Prepare final report	Summary of activities of the stages and the results of the evaluation

SUMMARY

The use of systems analysis procedures for the development, implementation and evaluation of an information management system is a time and resource consuming process. Due to this fact, the school's central administration must have a strong commitment to the development of an integrated information management system that will facilitate decision making. This commitment must be considered when the functional areas are being selected. If the costs of utilizing the procedure outweigh the expected benefits of automating a functional area, perhaps a subset of the development procedure should still be performed to assure that the automated function integrates with the rest of the information management

system. This method of developing an administrative information management system can also be employed in the development of other types of school software where a systems approach to development and incorporation into a school wide database is considered desirable.

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DEFINING THE ROLE OF CALCULATORS AND COMPUTERS IN THE LEARNING AND TEACHING OF SECONDARY SCHOOL MATHEMATICS

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While the instructional implications of all forms of instructional technology (e.g., slides, films, transparencies, demonstration devices, laboratory materials, television, calculators, computers) demand continuing attention, the curricular prescriptions presented in this paper focus upon the uses of calculators and microcomputer systems as tools in the teaching and learning of secondary school mathematics. Those prescriptions assume that both calculators and computers are, or soon will be, readily available to all secondary school students, and that calculators and computers should be employed as standard mathematical tools in the course of classwork, homework, and evaluation activities.

Student Access to Calculators

Most secondary school students do have access to calculators. As early as 1978, NAEP data confirmed that 80 percent of thirteen-year-olds either owned a calculator or had one available for use (Carpenter, 1981). It should now be a small matter for schools to supply this educational resource (as it does textbooks) for those who cannot afford to purchase it. Moreover, further hesitation owing to concern for possible negative outcomes resulting from the use of calculators is not justified. In fact, most studies either show no significant differences in the achievement measures of calculator and noncalculator groups or show differences in favor of the calculator group (Suydam, 1980; Suydam, 1981). It has been suggested that the lack of a body of evidence clearly favoring the use of calculators within the secondary mathematics classroom is probably due to the trivial tasks to which calculators are applied in many studies (e.g., checking answers), the failure to develop instructional materials which build upon the strengths of the calculator, and the limited attention given to integrating the calculator into the curriculum rather than using it in supplementary activities (Roberts, 1980). Relevant research activity, declining in volume after a period of intense interest prior to 1980, has provided evidence that the use of the calculator enhances the learning of problem-solving and basic paper-pencil skills (Driscoll, 1982; Hembree & Dessart, 1986).

To a degree, access to calculators is controlled by teachers and institutions (e.g., school boards and government agencies). However, a recent survey by the National Council of Teachers of Mathematics (NCTM, 1986) found strong support within its membership for the integration of the calculator into mathematics programs at all grade levels in homework, classwork, and evaluation. Over 74 percent of the sample group favored such use, the endorsement being 78% at the secondary level and 90% among supervisors of mathematics instruction. And while it is the policy of many state departments of education to encourage the use of calculators in secondary mathematics instruction and evaluation, such use is mandated in Connecticut, Missouri, Rhode Island, Texas, and Utah (Kansky, 1987). In Connecticut and Missouri, the availability of calculators is prescribed during administration of state-mandated mastery tests in secondary school

mathematics. California will include calculator-based items on the 1987 version of the twelfth-grade mathematics test which is administered as part of the California Assessment Program ("Calculator Breakthrough," 1986). In fact, the use of calculators throughout mathematics instruction and/or on all tests except the SAT has been proposed by the National Council of Teachers of Mathematics, the Conference Baord of the Mathematical Sciences, the Mathematical Sciences Education Board, the National Science Board, and the Mathematics Association of America ("Calculators in the Standardized Testing of Mathematics," 1987).

Student Access to Computers

Until recently, student access to computers has been defined in terms of access to microcomputers. The purpose of such access usually has been drill activity or the study of the computer itself as part of units on programming or computer literacy (Becker, 1985). In this regard, at least one computer is available in 95% of all middle/junior high schools and in 97% of all high schools. The proportions of such schools having 15 or more computers available for instructional purposes were 47% and 68% (Becker, 1986).

The introduction of handheld pocket computers with graphics capabilities and the companion instructional intent of using the computer as a tool in problem solving demand redefinition of "access" and give credence to the assumption of ready availability in the near future. Unfortunately, given this new technology and new focus for the use of the computer in the mathematics classroom, a research base for the suggestions to be made here simply does not exist. Moreover, generalizations suggested by recent meta-analyses of research on instructional computing offer no help, since the results are based upon studies most of which (a) predate microcomputers, (b) were executed on postsecondary populations, and (c) investigated tutorial, drill, or practice applications (Kulik, Bangert, & Williams, 1983; Kulik, Kulik, & Cohen, 1980; Roblyer, 1985). For the moment, then, curriculum-wide integration of computers as problem-solving tools must be guided by best guesses, creativity, and continuing research.

Again, our task is to explore the integration of technological devices into a curriculum. Both the devices (calculators and microcomputers) and the curriculum (secondary school mathematics) have been around for some time; the interaction between the two has already begun. Before setting forth any prescriptions, therefore, let us digress in order to clarify the use of the word *curriculum* and to summarize the history of interaction between one item of technology (which I will refer to as 'The Device') and the mathematics curriculum.

The Precollege Mathematics Curriculum

A common characteristic of recent proclamations regarding the content and delivery of the precollege mathematics curriculum has been the casual use of the phrase 'the precollege mathematics curriculum'. The unwary reader or listener is in constant danger of implicitly accepting the existence of *the* precollege mathematics curriculum. In fact, *the* curriculum does not exist. Examination of the history of mathematics education in America suggests that *the* curriculum never has existed. It is the hope of most mathematics educators that it never will exist. What does/did/will

exist is a plethora of local responses to public statements about the goals of precollege mathematics education; the sum of those responses is complex, internally conflicting, and ever-evolving. To an extent, these local responses are guided by national efforts at developing innovative secondary school courses and curricula (Hirsch & Zweng, 1985; National Council of Teachers of Mathematics, 1985).

The Second International Mathematics Study adds a further caveat to the discussion of any curriculum. This inquiry into the secondary school mathematics curricula of 24 countries was conducted during 1981-82 and included a subsample of 250 schools from across the United States. One conclusion of the study, a conclusion that held across the participating countries, was that any secondary school mathematics curriculum exists simultaneously in three forms: intended, implemented, and attained (Crosswhite, Dossey, Swafford, McKnight, & Cooney, 1985). An *intended* curriculum is defined by the goals or content specifications set forth by a state or local education agency; it gains further expression through the publication of curriculum guides or the adoption of textbooks or other instructional resources. This intended curriculum subsequently is translated by teachers into specific classroom activities and time allotments. These actions of teachers effect an *implemented* curriculum comprised of the content and procedures actually presented in the several classrooms of an educational system. But what is presented is not necessarily what is delivered. The third curriculum, the *attained* curriculum, is comprised of the mathematical concepts, generalizations, skills, and attitudes learned by the students of that educational system. Each student serves as a final filter in the transition from the curricular intentions of the system to the curricular attainments of the individual.

One objective proposed for the intended secondary mathematics curriculum is the use of technology to enhance the study of mathematics (Corbitt, 1985). The pursuit of that objective must go beyond the application of a layer of technology to the existing curriculum (in the manner in which chapters on sets and functions were added to the curriculum of the Fifties to create the illusion of a "new math"). The availability of powerful technological tools which manipulate both numbers and symbols with speed and accuracy dictates that the content, organization, and delivery of the curriculum must be open to question. As Fey (1984) notes, the degree to which the attained curriculum will reflect the aspirations of whatever intended curriculum may emerge from current deliberations will depend upon how well research, intuition, inservice, and teacher creativity can answer the curricular questions raised. It also will depend upon our understanding of the past history (and our control of the future history) of The Device. In the final accounting, efforts to create electronic curricula in precollege mathematics must be judged, in part, in terms of their success in producing students who can make appropriate uses of technology in solving mathematical problems.

Applying The Device to the Curriculum: A Glance Backwards

The Device found in today's classrooms has evolved from a first generation of such devices designed for use by the military during World War II. Second-generation models found in the schools as early as the 1950s were cumbersome and expensive but were introduced with the belief that their use would provide a new dimension to instruction. However, the absence of inexpensive, relevant, commercially-produced instructional

materials to support the application of The Device to the study of mathematics retarded the integration of this promising item of technology into the teaching of precollege mathematics. While creative, dedicated mathematics teachers did seek to develop such materials, the cost in professional time was often excessive and the materials produced dealt with isolated topics rather than major curricular strands. Although teachers were willing to share these instructional products, free exchange was often confounded by personal differences in instructional style that were expressed through the materials.

The introduction of a third generation of cheaper, lighter, and more powerful machines has been accompanied by further efforts to make them useful in the teaching of mathematics. Commercially-prepared materials now are available for several mathematical topics; major publishing companies have generated exemplary materials as components of "teaching packages" to accompany their textbooks. Still, the purchase of such materials for each classroom is beyond many school budgets. Schools that have purchased hardware for the mathematics classrooms now are demanding answers to questions about what creative uses can be made of these items of technology and what instructional improvment will be effected by those uses.

Teacher workshops and professional publications notwithstanding, the appropriate application of The Device to the teaching of mathematics generally has been left as an exercise for the individual classroom teacher; presentations at NCTM meetings have provided ample evidence of teachers' innovative responses to the challenge. Still, after 30 years in the schools, its curricular impact within many classrooms has been limited to duplicating selected functions of the 150-year-old chalkboard.

Caveat Emptor

We pause here to make four observations. First, The Device described in the three preceding paragraphs is the overhead projector; the remarks were generated by using a word processor to replace each occurrence of 'the overhead projector' by 'The Device'. Second, the statements that would result from replacing each occurrence of 'The Device' by 'the microcomputer' would be equally true. Further replacement by 'the handheld calculator' also would be appropriate. Third, whereas the overhead projector really did not have the potential to effect any substantive change in the content and organization of the mathematics curriculum, the calculator and the microcomputer do. Fourth, the curricular prescriptions which follow are based on the assumption that such change is inevitable.

Any savvy educator will tell you that everybody knows that devices alone will not improve instruction. But if everybody knows that, knowledge once again appears to have fallen prey to hope as educators (and the lay public) have stretched budgets in order to purchase computers--and, with less enthusiasm, calculators--in the absence of any plan for their integration into the several curricula (e.g., mathematics) which supposedly demand their presence in the schools. Thus, while computing technology has become available for instructional purposes, there has been little consideration of what those purposes might be or of the goals that they serve.

Of the several ways in which calculators and computers might impact upon the mathematics curriculum, only two are discussed here. The first is a consequence of the belief that it is mathematics itself (rather than the textbooks or curriculum guides) that suggests the form of technology best

suited to the investigation of a given problem. Since the problem solver is given the charge of recognizing that "suggestion," criteria are offered to help in matching mathematical tasks with appropriate technological tools. The second dimension of change, the use of the microcomputer to aid mathematical problem solving, is addressed through the discussion of the possible uses of three types of electronic courseware, where the term 'courseware' should be understood to mean microcomputer software accompanied by teacher guides, printed student materials, or laboratory activities. Such courseware is examined in terms of its potential applications in developing the mathematics curriculum, expanding the instructional options of teachers, and supporting the mathematical investigations of students.

Appropriate Technology as a Function of the Mathematical Task

The computational component of the secondary school curriculum calls for the use of three forms of technology: paper-pencil, calculator, computer. Each form is the best choice for certain applications; no form is superior for all applications. The student who is to make "appropriate use of technology" must know more than how to use any item of technology -- he or she also must be able to decide which item is best to use in any given situation.

Calculator Tasks

It has been suggested that there are five criteria that might be applied conjunctively in helping to identify computational situations best served by the use of a calculator (Kansky, 1987):

- the student knows how to interpret the results obtained;
- a moderate number of complicated calculations is required to test some mathematical idea or pattern;
- it is unlikely that patterns will be obscured by the decimal format of the results;
- a limited electronic memory will suffice, since only a few variables are involved; and
- no detailed record of intermediate or final results is needed.

The first of these criteria does not ignore the broader principle that any numerical result, regardless of how it is obtained, should be interpreted in terms of the original problem situation. Rather, it is meant to direct attention to the student error of reporting results with false precision, a problem that has been compounded by the ease with which a calculator (or computer) can generate figures to several decimal places. For example, a student who has measured the legs of a right triangle and reported them as 31 cm and 44 cm should realize that it makes no sense to report the calculated length of the hypotenuse of that triangle as 53.823787 cm. The use of calculators, coupled with greater curricular attention to problems which involve real data (i.e., measurements), will require increased attention to the reasonableness of results in terms of rules that govern calculations with approximate numbers. Instruction which promotes understanding of the approximate nature of measures (Kerr & Lester, 1976) must be augmented by the development of guidelines for "rounding" the results of calculations performed upon approximate numbers.

Example 1. If developing problem solving strategies is to be the centerpiece of the mathematics curriculum, calculations necessary to the

exploration of a problem must not be allowed to interfere with the exercise of problem-solving strategies. Solving the following problem aided solely by pencil-paper (rather that a calculator) should be viewed, then, as being poor mathematical procedure.

> It has been estimated that America's coal reserves will last 200 years at the current rate of consumption. However, it is predicted that coal consumption is increasing at a rate of about 4 per cent each year. If that prediction is correct, about how many years will it take to double the current consumption? To triple it? To quadruple it?

Example 2. The next problem -- a nonroutine problem intended to exercise several problem-solving strategies -- illustrates the difficulty of applying even the simple criteria that have been proposed. In doing so, it verifies that the goal to teach students "to make appropriate use of technology" is not a trivial one.

What exactly is the sum of the first 450 terms of this sequence?

$$\frac{1}{471}, \frac{1}{472}, \frac{1}{473}, \frac{1}{474}, \ldots$$

The nature of the task suggests that we calculate the first several terms of the 450-term sum and look for some pattern that would permit an inductive leap to the solution of the problem. Because the numbers are nasty, our impulse is to use a calculator or computer to hammer out the solution. But since an exact solution (rather than a decimal approximation) is required, our electronic hammer has the effect of bending the pattern out of shape. On the other hand, a combination of paper-pencil technology and a bit of problem-solving prowess yields both quick rewards and significant mathematical insights.

Computer Tasks

Four criteria might be applied to identify computational situations calling for a computer.

- The student knows how to interpret the results obtained; and
- a large number of repetitive calculations or comparisons is required to test some mathematical idea or pattern; or
- a large data set will be used repeatedly over a period of time; or
- a detailed textual or graphical record of intermediate or final results is needed.

With the exception of the first criterion, the criteria are to be applied disjunctively. Thus, once it is assured that the student is able to interpret the results of the calculations, any one of the other conditions would be sufficient to justify the application of a computer. The repeated use of an algorithm, repeated use of a data set, or generation of long/complex output are tasks requiring prodigious feats of memory, speed in applying a well-defined procedure, and unflagging attention to tedious details -- requirements perfectly matched by the fundamental talents of a computer.

Example 3. While the initial investigation of a mathematical idea might proceed nicely with the aid of just pencil-paper or a calculator, it sometimes becomes evident that the resolution of a question depends upon the repeated application of a multi-step procedure. Consider this problem.

> The marching band at Very High School decides to sell earmuffs ($3 profit per pair) to earn the $2400 needed to pay its way to the state tournament. Two local service clubs agree to

help. One club offers to contribute 50 percent of whatever the band takes in from earmuff sales or *from other contributors*; the second club offers a 75 percent contribution under the same terms. Band members sell 204 pairs of earmuffs. Is the help promised by the two service clubs enough to allow them to make the trip? If not, what minimal number of earmuffs must be sold to make the trip possible?

Although elementary algebra could be used to organize a solution to this problem, a guess-and-compute strategy will do the job. In either case, the calculations required during repeated executions of the strategy are burdensome even when done on a calculator. A computerized form of the algorithm is the tool needed.

Paper-Pencil Tasks

Criteria for employing paper-pencil technology are placed last lest they be overlooked. Use of this form of technology might be deemed appropriate when

- the student knows how to interpret the results obtained; and
- a small number of calculations is required to test some mathematical idea or pattern; or
- a rough approximation is satisfactory; or
- the focus of instruction is practice in the execution of a specific algorithm.

The last of these criteria acknowledges the need to develop a modicum of facility in executing selected computational algorithms. Clearly, paper-pencil technology is the correct tool to use on each problem of a problem set devoted to a particular algorithm, since each application of the algorithm constitutes a separate task. Viewed as a whole, however, the problem set calls for the repeated application of an algorithm to several different pieces of data -- that is, the entire set suggests a situation suitable for solution by a calculator or computer. Thus, a student makes a legitimate use of a calculator/computer when checking his/her facility in the use of the algorithm which is the object of study. Teachers, quick to recognize that such use provides feedback to the student without teacher intervention, have made "checking" a major application of the calculator (Graeber, Rim, & Unks, 1977; Wyatt, 1979). In accepting this complementary relationship of paper-pencil and calculator, *it is equally important to give explicit attention to the application of the paper-pencil skill of making rough approximations to "check" the reasonableness of the results generated at each step of calculator use.*

Example 4. The conclusion to many simple problems is a yes-no decision based upon mental or paper-pencil manipulation of approximate numbers. The problem below, for instance, should be so treated. Its resolution requires only a quick calculation with a "rounded" figure.

> Tickets to a concert are $11.75 each. Is $50 enough to purchase four tickets?

Example 5. Other problems are similar to the task of "checking" the work done by a calculator. That is, the results of a calculation are known; the task is to decide whether that result is reasonable without duplicating the details of the calculation procedure. Here's such a problem.

> Lou uses a calculator to divide 21 by 0.3 and gets 70. Does this seem like a reasonable result?

Putting the Microcomputer to Work in the Mathematics Classroom: A Problem Solver's View

Thus far we have focused our attention on criteria for matching items of technology with mathematical tasks. Insofar as the computer is identified as the appropriate tool, it is assumed that relevant software is available to the problem solver (student or teacher). These software tools of the mathematical problem solver can be sorted into at least three categories: commercially-prepared applications software tools, teacher-generated software tools, and student-generated software tools. Because the latter two categories require programming skill of either the teacher or the student and because the majority of teachers and students do not possess the necessary skills, we will consider only the applications tools.

The term 'applications software tools' denotes complex commercial programs which manipulate, transform, or display data or mathematical expressions. Examples of application tools include databases, word processors, graph-generation packages, spreadsheets, statistical packages, and packages which assist in the construction, transformation, or manipulation of geometric shapes. Each such tool is of practical value, however, only insofar as the range of problems to which it may be applied is sufficiently large to justify the amount of problem-solver (teacher or student) time that must be invested in learning how to use the program. This criterion of practicality also is a function of the level within the teaching-learning process at which the application is made: curriculum development, classroom instruction, or student use.

Curriculum Development

A curriculum which is textbook-based is harnessed to a adoption schedule of three to five years. Except for minor corrections introduced during reprintings, textbooks themselves are locked into a five-year schedule by the extreme expense of substantive revision. Teachers seeking to update or enliven such a curriculum currently are faced with the task of locating and/or modifying supplementary materials which match the interests and abilities of their students. Maintaining such a resource file and using it effectively can demand considerable time and space. It can, but it need not.

Consider the task of infusing problem-solving activities into all strands of a secondary school mathematics curriculum. The resource needed is more than a large collection of appropriate problems. It is a collection in which each problem is categorized by such use variables as mathematical strand, problem-solving strategy, instructional intent (e.g., to develop a new topic within one of the strands or to take a given concept to a higher level), instructional extent (isolated task, series of tasks, project), student grouping (individual, pair, small group, whole class), and technological tools needed. Computer integration of a word processor, graphics package, database, and communications package could be used to put such a collection of problems (and related teacher-support materials) at the fingertips of the classroom teacher. The sorting power of the database could be used to locate problems needed to fit a particular application. The word processor and graphics utility might offer the teacher the opportunity to "localize" problem situations by using names of persons and places familiar or of interest to the students, to alter out-of-date data, or to modify the problem to suit a different audience. Modification of the primary set of problems could be carried out instantaneously; the revised resource being

delivered over the communication system; bulletin boards and mailboxes on the same system might be used by teachers and students wishing to share new problems and/or problem-solving ideas.

Classroom Instruction

Mathematics teachers interested in solving instructional problems will find it profitable to learn to operate several of the applications tools. When used in conjunction with a computer-projection system, these tools can be used to enhance whole-class instruction in what might be termed a demonstration mode of computer use (Dennis & Kansky, 1984). For instance, graph-generation packages can be used to match classes of relations with their characteristic graphs by quickly and accurately plotting representative families of those relations on each of several kinds of graph paper. Conversely, the plotting of experimentally-generated data points on several kinds of graph paper can lead to the identification of the class of relations which best fits the data. Use of a spreadsheet in the demonstration mode can support the classroom game of "what-if" as used to explore, say, properties of specific sequences. Statistics packages being designed for the middle school and high school can be used to conduct statistical inquiries by generating several alternative graphical summaries or numerical analyses of a given data set. The demonstration mode also can be applied to programs like *The Geometric preSupposer* (Schwartz & Yerushalmy, 1986) which aid in the construction, transformation, or manipulation of geometric shapes. Such demonstrations can be used to provide students with opportunities to conjecture and test geometric properties. Individually, demonstrations familiarize students with the operation and problem-solving possibilities of a particular application tool; collectively, demonstrations provide students with experiences in planning and executing useful problem-solving strategies.

Student Use

Teacher uses of applications tools should lead to comparable independent uses of those tools by students engaged in problem-solving activities. Such independent use does not require that the teacher instruct each student in the use of each electronic tool; neither does it require that each student develop high facility in the use of each tool. The desired independent use can be realized through the use of "teams" of problem solvers within which individuals take responsibility for learning to use particular tools and subsequently assisting other members of the team to apply those tools to investigate mathematical ideas. To date, little research has been done to investigate the effective use of computers as group problem-solving tools. However, an investigation involving eighth-grade students engaged in the study of a mathematically-oriented unit in geography concluded that cooperative learning was superior to competitive or individualistic learning with regard to the quantity and quality of daily achievement, the recognition of the factual information studied, the application of facts to test questions requiring higher level thinking, and success on complex problem-solving tests involving mapping and navigation (Johnson, Johnson, & Stanne, 1986). In fact, research on cooperative learning supports the assertion that the use of academically and socially heterogenous groups of five or fewer students will produce higher levels of achievement on complex tasks such as problem solving than

will competitive or individualistic learning environments. Peer teaching within the cooperative learning groups promotes not only positive interdependence among the members of the group but also the individual accountability of each member of the group (Johnson, Johnson, & Maruyama, 1983; Johnson, Maruyama, Johnson, Nelson, & Skon, 1981; Slavin, 1980).

The goal of having students make "independent use" of computers to solve mathematical problems does not imply a learning environment in which the teacher is responsible for developing the technological expertise of each student and in which each student works in isolation to apply that expertise to the solution of mathematical problems.. Rather, the application of the computer as a tool in the study of mathematics suggests the need to develop new student-teacher and student-student roles. A technology conference conducted under the auspices of the National Council of Teachers of Mathematics concluded:

- Teachers must serve as learning models in attacking mathematical questions. They must be comfortable assisting students in learning situations in which the topic being studied or the resource applied is unfamiliar. Teachers must be prepared to say "I don't know yet," while they join students in exploration.
- Teachers must become facilitators of cooperative learning as students engage in realistic learning projects that computers make attractive. Teachers and students must emulate real problem solvers as they deal with problems of complexity, accuracy, and precision that occur in the collection and analysis of real data.
- For students, the greatest promise and challenge of technology in mathematics learning is the move toward more self-directed and self-monitored learning. Students must become adept at using computer-based instructional materials, mathematical tool software, and personal programming skills to develop and practice the use of mathematical concepts, principles, and problem-solving processes. (Corbitt, 1985, p. 247).

Traditionally, the secondary mathematics teacher has assumed the role of bottomless knowledge source, while the student has assumed the role of knowledge receptacle. Traditional mathematics education is a process by which ideas are poured from the teacher into the student. The educational atmosphere is one which suggests that mathematics is a bounded set of ideas which are best transmitted in their most polished form. To keep such a system working smoothly, it was necessary that the questions asked by teacher and student be carefully controlled in order to assure that the required answers were available. The student-teacher interactions detailed by Corbitt place the teacher in the role of a partner in learning who knows how to make appropriate uses of the tools of inquiry (including technological *tools) to search for solutions*. In this educational atmosphere, mathematics can be presented as a growing body of ideas which the learner must be equipped to explore independently with the aid of technological tools and problem-solving strategies.

Summary

The availability of calculators and computers within precollege classrooms has increased steadily during the past 15 years; there is reason to believe that most students will have ready access to these forms of

technology by 1995. Thus far, however, planners and authors of secondary school curricula have failed to respond to the oft-quoted recommendation of NCTM that "mathematics programs take full advantage of the power of calculators and computers"(NCTM, 1980, p. 8).

This paper has explored two broad areas of curricular implications of calculators and computers. First, and on the assumption that appropriate applications of these technological devices are a function of the mathematical ideas being investigated, it has suggested guidelines for matching mathematical tasks with technological tools. Second, it has examined ways in which microcomputer courseware can serve curriculum development, teaching style, and student problem solving.

The nature of the discipline called mathematics has been forever altered by computers and, to a lesser degree, by calculators. As precollege mathematics instruction is altered to reflect that change, schools may present students with the first really "new math" since the founding of the United States.

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TELECOMMUNICATIONS: APPLICATIONS AND CONSIDERATIONS FOR USE

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The intent of the following paper is to present a descriptive account of the current status of telecommunications in general and of teleconferencing in particular. Within the past two decades concepts such as telecommunications, information processing, and information society have become an important part of our technical vocabulary. Information technology now conjures impressions of home computers, live satellite transmissions from any spot in the world on national television news breaks, computers that run our cars and check out our groceries, electronic banking, and instant identification verification.

While the invention of the telephone occurred over 100 years ago, instructional applications of this omnipresent communication device have occurred somewhat recently. One of the initial educational applications of the telephone occurred at Albany Medical College in 1955 where continuing education activities for health care professionals were offered to a neighboring region covering six states. Soon after that, Stephens College organized a small college consortium which used conference calls as the basis for exchanging information and instruction among seven colleges. In 1963, the Ohio State University medical school began using the telephone for instructional purposes, and in 1965 the University of Wisconsin Extension Telephone Network (UWETN) was organized. The UWETN system began with 18 listening sites around the state and today has more than 200 locations (Berk, 1982).

In business and industry, a movement to teleconferencing began with the audio-conferencing system of Bank of America in 1968. Since 1975, IBM has had its own system for still-video conferencing while Procter & Gamble employees have had access to their company's computer-based conferencing system since 1978. Video teleconferencing in business has been quite recent, with the systems at Aetna Life and Casualty Company and Hewlett-Packard being implemented in 1981 (Johansen & Bullen, 1984).

Definitions

There is a difference between telecommunication and teleconferencing, although the terms are frequently used interchangeably. Telecommunication encompasses all transfers of information, both internally and externally, to an organization by electromagnetic means, including telephone data, telegraph facilities, standard broadcasting and cablecasting satellite transmissions, and computer communication systems. (Penrose, 1984). Teleconferencing is subsumed under the broad domain of telecommunication. Teleconferencing is the process of interactive group communication through any electronic medium (Johansen and Bullen, 1984). One interpretation of the difference between these terms is that

telecommunication emphasizes the electronic network, while teleconferencing places emphasis on people using the network (Penrose, 1984).

There are three categories of telecommunication hardware used in teleconferencing: voice, print, and video. One important distinction among these forms of teleconferencing is the time element. If all participants are present simultaneously, the conference is synchronous. Presently, nearly all audio and video conferences are synchronous. In contrast, if participants can check into the conference when they wish, it is an asynchronous conference. This type of conference is exemplified by store-and-forward text communication of electronic mail systems (Johansen and Bullen, 1984).

Conferencing Applications

Voice Telecommunications

Audio teleconferencing is voice communication with at least two people connected by a traditional telephone link, or more plainly, a phone call is teleconferencing in its simplest, most common, and least expensive form. However, conference calls occurring in more than two locations and involving three or more people is generally thought of as the simplest form of audio-conferencing.

Audio bridges or telephone linking devices are used for teleconferencing. This bridge serves to open channels to all parties enabling them to communicate with one another. Dial-out bridges are generally handled by an operator who calls each location to link it into the network. With another bridge, dial-in bridges, parties dial at a predetermined time and are linked by the operator as the calls come in. An institution or company may purchase, lease, or rent bridges which will accommodate from 90 to 200 sites depending on the equipment configuration. Further, a number of companies now offer audio bridging services (Jenkins, 1983; Picot, 1984).

Audio teleconferencing can be augmented by iconic information such as slides, charts, graphs, documents. Freeze-frame or slow-scan techniques can be used to transmit visual images over phone lines onto a monitor or screen. This technological mix is called audiographic teleconferencing (Goldfield, 1983). A limitation of this technique is that typically images can be sent only on a single frame basis; further, audio signals cannot be sent while the visual is being transmitted causing a delay in the flow of information.

Several forms of voice teleconferencing occur in educational settings. In telelectures, for example, the presenter and receivers can hear each other, but there is a one-to-many structure. The "one" person is the lecturer who provides a presentation to a "class" at multiple sites. A related example is telephone instruction. In this application, permanent headphones and microphones are present in a classroom where the receivers are congregated (Penrose, 1984).

Business applications of teleconferencing appear to serve information-gathering functions very well. Information regarding availability of equipment, production schedule delays, whereabouts of key people, suggested policy changes, and ideas for handling technical problems with the company's equipment are representative of information topics that can be addressed very efficiently with voice-teleconferencing (Jenkins, 1983).

There are both disadvantages and advantages to voice teleconferencing. Listeners tend to give audio-conferencing low marks

regarding affective aspects of communication due to the lack of a visual referent. Second, discussion doesn't occur without substantial and sustained effort. It must be planned and encouraged. Third, focusing attention on an audio speaker for an extended period of time when there isn't a visual referent is unrealistic. Fourth, the communication cycle isn't complete until the sender receives feedback, such as non-verbal cues. Finally, the telephone has a low data rate, that is, narrow bandwidth (3000 Hz), which limits its usefulness for teleconferences (Penrose, 1984).

The major benefits of voice teleconferencing are its low relative cost, its broad geographic access, and its speed of transmitting information. Jenkins (1983) indicates the cost of a face-to-face meeting is at least 15 times greater than that of an audioconference, based on customary business travel expenditures. Associated with these benefits are the savings in time and stress associated with lengthy distances to be traveled during inclement weather, as well as the difficulty of leaving one's work (Anderson, Chute & Raszkowski, 1982; Parochka, & Miller, 1984).

Goldfield (1983) indicates that audio teleconferencing accounts for at least 90 percent of the teleconference market due to its relatively low cost and high adaptability. Audio teleconferencing costs depend on three principal factors: long-distance charges, the cost of bridging the participants ,and the expense of any specialized equipment. In 1983, the typical cost was $45 per hour for each phone line. To illustrate, ten executives in different locations could hold a one-hour meeting for $450 excluding the rental of special equipment.

Print Telecommunications

After the telephone, the most frequently used telecommunications device is a facsimile machine. This device transmits and receives documents such as letters, illustrations, graphs, and schematics. The device functions like a copying machine that sends its product over a telephone line to a distant site (Penrose, 1984).

Other print telecommunication techniques include: freeze-frame video whose signals are sent over regular telephone lines and are received on a television monitor; electronic blackboard, a device that converts writing and drawings on a "blackboard" to signals which are transmitted over telephone lines to a distant television monitor; telewriters, a system which uses an electronic tablet and pen or a keyboard to send messages over phone lines to a distant video screen (Goldfield, 1983). The highest level of print telecommunications in terms of interaction and speed-of-feedback is computer conferencing. Computer conferencing can be used for electronic filing, work documentation, word processing, and electronic mail for educational and managerial purposes (Penrose, 1984). However, conferencing with computers requires keyboarding and computing skills which managers, executives, and consultants may not have acquired.

The following benefits and limitations of print telecommunications in this discussion are based on the capabilities and characteristics of computer-based message systems or "electronic mail" (Penrose 1984). Advantages of electronic mail are that it can be sent certified with receipt acknowledged; can go directly to Western Union; and can save phone charges, word processing costs, as well as paper and duplicating costs. Disadvantages of electronic mail are that it requires special equipment (computer systems); is linked to commercial networks which often have minimum usage requirements, which in turn affect costs; and requires specialized skills.

User groups for print telecommunication technology include educators, managers, and executives who share common objectives and use this medium as a means of sharing their ideas with one another. Unlike the literature on audio conferencing which documents the cost of establishing and conducting teleconferences by audio, no information was found on the costs of print telecommunications. Certainly the cost would be higher to conduct a print telecommunication conference since the specialized equipment for sending and receiving the information would be more extensive than that required for audio conferences.

Video Telecommunications

Video teleconferencing occurs in two forms, point-to-point and point-to- multiple-points. The essential elements of these complex and relatively expensive forms of teleconferencing are high quality audio systems and full motion color video systems. Point-to-point teleconferencing involves at least two locations with audio and video signals going to and from each location. This type of video teleconferencing often originates in studios; the late news program *Nightline*, illustrates this form of conferencing. Point-to-multiple-point teleconferences generally involve sending a one-way video signal from one location to many others, while providing interactive video signals among the stations (Picot, 1984).

Goldfield (1983) estimates the outfitting necessary to implement point-to-point video teleconferencing for each location costs from $250,000 to $500,000. These figures are substantially higher than those cited for establishing audio teleconferences and reveal why video conferencing has been implemented on such a limited basis. Yet proponents of video conferencing cite this technology's ability to bring together individuals from many different locations to share ideas, graphics, and data while saving both time and money, primarily from the avoidance of overnight travel. Ferebee (1984) notes a number of value-added benefits that can accrue from the application of this technology. For example, she cites the nonproductive time that managers, instructors, and executives spend traveling that can be recovered if teleconferencing is used. Second, teleconferencing enables a more efficient use of personnel resources by keeping key people on the job, rather than traveling to a meeting site. Third, communication is instantaneous, thus improving response time for timely decisions. Fourth, teleconferencing enhances the flow of communication and increases personal involvement of employees at remote sites, who generally do not travel to face-to-face meetings. Fifth, when quality of life is considered, teleconferencing can reduce stress on employees by reducing extensive travel while increasing opportunities for home and leisure activities.

Videoconferencing can be used to reach more people and attract noted speakers. To illustrate, one source cited a recent case where an evangelist staged a world-wide teleconference that reached a half-million viewers. Moreover, companies can avoid the cost of purchasing equipment by using the services of firms specializing in video teleconferencing. For example, Holiday Inn currently can receive satellite communications at 300 locations, and Marriott is establishing video teleconferencing capabilities at a number of hotels.

Disadvantages to video conferencing are just as numerous as the preceding list of benefits. Because of the bandwidth requirement for motion video (12/14 GHz), video signals cannot normally be transmitted over telephone lines. Due to this property of motion video technology, costly

microwave transmission systems such as relay towers or satellites are needed to transmit the signals between stations.

Concerning human factors, some users have complained about feeling awkward and uncertain while participating in video-teleconferences. Penrose (1984) cites an observation that people who meet for the first time in a video conference form neutral to negative impressions of each other. An explanation for these "first impressions" is that television doesn't transmit non-verbal cues very well and personalities don't seem to emerge.

In fact, executives participating in video conferences run the risk of being perceived as incompetent by individuals whose only acquaintance is through the teleconference. Moreover, many participants report video conferences are too impersonal when compared with face-to-face meetings. Further, travel between sites isn't necessarily perceived as unpleasant; rather, traveling appears to be perceived as an indication of enhanced status by individuals who take fewer than five business trips a year (Sloan, 1984).

With the exception of financial considerations, disadvantages of video conferences appear to be linked with inadequate planning. Morton (1982) suggests the following steps to enhance the quality and effectiveness of video conferences.

-Identify conference goals and plan accordingly;
-use appropriate technology such as computer graphics, video-tape presentations;
-prepare participants with an agenda sent in advance of the meeting;
-structure the question/answer session to be essentially spontaneous, if possible;
-organize props, cueing, and lighting, and check the sound system;
-allow yourself to become accustomed to the set while working on being composed and relaxed; and
-prepare for the psychological challenge of "doing well" in the videoconference.

Given the benefits and limitations of videoconferencing, it appears this medium is functional in a variety of settings for teaching, sharing information, providing directions, considering policy issues, and problem solving.

General Considerations

Teleconferencing is developing into an industry as the range of products increases and their quality advances. The variety of systems available for purchase or lease appears to be expanding rapidly. Yet misconceptions by potential users have occurred and likely will continue to occur, resulting in the disappointment and frustration of individuals who are pioneers of this technology. Johansen and Bullen (1984) have listed some of the most common misconceptions as follows:

1. Teleconferencing will reduce traveling to meeting sites. Most institutions and companies who have invested in teleconferencing were influenced by the idea that teleconferencing would cut down on travel. Ironically where teleconferencing has become an integral component of the communication network, travel has not diminished. Rather, more people have become involved in conferences. Thus, teleconferencing, when it works, changes the way organizations communicate. Travel patterns may change, but experience indicates teleconferencing does not substitute directly for

travel. Yet travel statistics are the most defensible justification for making the necessary expenditures associated with teleconferences.

2. Audio teleconferences are simple to implement and to use. New users are often surprised that audio systems are the most technically difficult component in teleconferences. The acceptable range of video quality in teleconferencing is much broader than that of audio. For example, slightly fuzzy pictures of participants or less than desirable graphics will not ruin a meeting, but the inability to hear what is being said will. This misconception becomes significant when decisions are made to invest heavily in the latest video equipment while saving on audio components. Ironically, just the opposite should occur to increase the success potential of teleconferences.

3. Teleconferences serve as a substitute for vis-a-vis meetings. It is not uncommon for users to try creating teleconferencing systems in the image of face-to-face communication. In attempting to establish a system for accomplishing this substitution, designers of the teleconferencing system may neglect the culture of the group within the organization who will use the system. Culture in this sense is the setting elements that guide the behavior within a group such as the shape of conference tables, type of chairs, and thickness of carpeting. Unfortunately, many teleconference rooms are more consistent with the culture of the telecommunication designers who built them than with the culture of the intended users. In other words, setting up an electronic meeting room for executive officers in a fashion similar to a briefing room for technicians would be in error since the trappings of their esteemed positions would be absent.

On a different note, computer conferencing systems provide opportunities for vastly different forms of communication than face-to-face meetings. This technology allows participants to come and go according to their own schedules. They remain in their own work environment, thus having access to resources while structuring their position or response. Meetings in this sense have very different characteristics than face-to-face meetings and require different communication skills.

Teleconferencing is being viewed increasingly as a branch of information systems technology because of its potential for getting information directly from people. Johansen and Bullen (1984) note the reliance of people upon seeking information from colleagues before searching written sources. This phenomenon is further encouraged by teleconferencing since it is becoming easier to assemble the right people at meetings or to have them leave messages via electronic mail. Presently, it is possible for teleconference participants to engage computer-based models to evaluate alternate proposals. For example, during a teleconference, participants can test different hypotheses immediately by changing the parameter of their decision model then generate outcomes based on the new assumptions and conditions. This capability combined with computer graphics and information processing allows reports or, at least, preliminary reports to be developed during the meeting and to be immediately transmitted to all participants (providing sufficient equipment is available at each conferencing site). These technological capabilities are creating the need for persuasive linguistic skills. As Mills (1984) notes, the impact of an executive's physical presence will be displaced by the artfulness and look of their online discourse. As the need for greater verbal fluency alters roles, a corresponding change in the organization occurs. The organization that relies on teleconferencing will place less emphasis on formal hierarchies. Teleconferencing, particularly via computers will likely open new channels of communication that tend to flatten hierarchical structures in organizations. This new structure will provide opportunities for young staff

in remote locations to communicate directly with those in power, thus reducing the "power" and advantage of those who work at the "home office."

This high-tech form of teleconferencing also can have negative aspects especially for the emotional well-being of the people in the organization. Troubled managers using this technology can keep in closer contact with, and thus exert greater control over, people working under their direction. This situation, typically results in lower morale, less job satisfaction, and diminished trust of the manager. Further, reducing the number of face-to-face encounters with colleagues could narrow rather than expand professional contacts and restrict opportunities. Moreover, affective aspects of communication which are lost entirely by teleconferencing, such as a stern look, a supporting hand on the shoulder, an encouraging wink, are important in the lives of people who work together and certainly influence morale. Because teleconferencing changes communication, prudent administrators who are considering whether to introduce this technology into their organizations must consider a myriad of issues such as, costs, type of teleconferences, advantages, limitations, and possible changes of the organizational structure in coming to a decision. If carefully considered, teleconferencing can become an important and beneficial part of an organization whether the organization is a Fortune 500 company or a university with multiple campuses.

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EDUCATIONAL COMPUTING: A GOOD BUY FOR K-12 EDUCATION? MAYBE NOT

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By the mid 1980's over one billion dollars had been spent purchasing microcomputers for the nation's K-12 schools. Generally, they have been purchased to help teach computer literacy and programming courses and to augment traditional instruction through the use of computer assisted instruction (CAI) programs. In many states, computer literacy and computer programming courses are mandated. Now that the novelty of instructional computing is beginning to wear off and budgets are becoming tighter, school personnel are, more than ever, expected to be able to demonstrate how the dollars that are spent on educational computing result in improved instruction. What about educational computing? Is it paying its way?

Because CAI characterizes a majority of the attention given to educational computing, an overview of the state of CAI effectiveness research and some ways in which educators can demonstrate a pay-off for their investments in educational computing are discussed. The paper ends with a conclusion that, for now, better use of educational computing resources will result if they are used to develop programs to "empower" teachers rather than to teach students.

The Extent of Educational Computing

By 1983 fifty-three percent of all American schools and eighty-three percent of high schools had at least one computer (Levin, 1984). However, according to Becker (1985), fewer than ten percent of those schools had as many as fifteen computers, and these computers were more likely to be used for computer literacy and programming courses than for any other application. When computers are used for purposes , drill-and-practice applications far exceeded other uses (Becker, 1985, p.7). Other findings reported by Becker are summarized below:

> The use of computers for drill-and-practice declines as a function of how long a school has used computers. (p. 9)
>
> The typical elementary school micro was used eleven hours per week; the typical secondary school micro was used thirteen hours per week. (p. 6)
>
> Students who do use computers, use them a median of twenty-three minutes a week at the elementary level and forty-five minutes a week at the secondary level. (p. 11)
>
> Typical elementary drill-and-practice students received less than twenty minutes practice time per week. It is doubtful that they could have made substantial progress in that time. (p. 13)
>
> In schools where teachers led the acquisition, computers were used almost twice as often as they were in schools where a single teacher, or administrator, made the decision to acquire. (p. 21)

Instructional Effectiveness of CAI

Level of achievement, student attitudes, time required to master material, and retention have all been analyzed in CAI effectiveness research. The studies typically compare students' learning when their instruction is augmented with CAI against students' learning under "traditional" instruction. The most "optimistic" studies show that, when instruction is augmented with CAI, students learn more in less time, they remember the material longer, and they feel better about the learning that has occurred than they do when CAI is not provided. Probably the most widely quoted studies are the meta-analyses conducted by Kulik during 1981 through 1984.

Roblyer (1985) summarized Kulik's and other CAI effectiveness studies and provided a concise report with an extensive bibliography which is an excellent reference for those who wish to examine those studies in more detail. Dalgaard, Lewis & Boyer (1984), who also examined several CAI effectiveness studies, reported a reduction in instructional time of thirty to ninety percent, a higher achievement of one to one and a half standard deviations (or thirteen percentiles), and better attitudes toward computers. But these results are not consistent across grade levels, subject areas, or student abilities. Effectiveness has been demonstrated to be more noticeable at lower grades and for below average students than it has been for students in upper grades or for those students who are already high achievers (Way ,1984; Okey, 1985; Roblyer, 1985).

Other research reviewers are more modest in their interpretation of CAI effectiveness studies. For example Slesnick (1984) reported that computerizing drill and practice in mathematics reduces the amount of time on task, but that other claims are unsubstantiated by research. She further noted that the small number of studies and conflicting results prevent many conclusions about the effectiveness of computer simulations in the classroom.

Nevertheless, the conclusions of such studies might be used to justify the expenditure of a local education agency's educational computing funds on CAI. To build the case, one can report as did Okey (1985, p. 8) "There is no doubt that research and evaluation findings strongly support the use of computers in instruction." Or note as did Dalgaard (1984, p. 313) "there appears to be little doubt that students can be taught with computers in less time than with conventional methods... ."

But, there are several other important issues that need to be considered before one can conclude that CAI is effective in improving instruction in every school, and that it is a cost effective means to improve instruction. Examination of Becker's findings, for example, indicates that even though there is research evidence that CAI can be effective, schools have not yet found how CAI can be effectively implemented. Even in cases where CAI has been effective, determining whether or not it has it been a cost effective means to improve education is important to those concerned with educational accountability.

Cost Effectiveness of CAI

Even where CAI has been demonstrated as being effective, it has not been shown to be the most ecnomical way to increase instructional effectiveness. If education's goals is to increase effectiveness, better cost/benefit ratios might be found using other strategies.

There are several explanations for this phenomenon. First, there is a dirth of quality software. One recent evaluation (Education News Service, 1985) reported less than three percent of software available for CAI was of sufficient quality to unanimously recommend. The software evaluation house for the New York City public schools purports to have one of the largest software data bases in the world, but has identified only 200 programs out of 10,000 as being useful. (Bonner, 1984)

Second, schools often lack adequate funds to implement CAI at levels required to make it effective. Because schools either do not have the resources needed to purchase enough computing resources to make CAI effective or don't use available resources effectively, there is slim hope to demonstrate wide-spread CAI effectiveness. Becker (1985) found that "In many cases a child must spend an hour doing 'busy work' in order to get a ten minute turn on a classroom computer--perhaps a turn shared with a 'partner.' It is possible that the more motivating and more effective instructional time at the computer is offset by a decline in the quality of learning that occurs during the 'waiting time,' compared to prior instructional practices. Becker continued "...because it is too costly for schools to assign a teacher to supervise fewer than a classroom of students, most schools use their computers less than they would prefer." (p.3)

Valdez (1986) reported that students need at least forty-eight to sixty minutes of quality computer-assisted instruction times a week to demonstrate significant improvement in learning. If this is the case, and if students are typically averaging less than twenty-five minutes a week on the computer with much of that time being used for activities other than CAI (Becker, 1985), there is no reason to expect that educators will be able to demonstrate how CAI is paying off in K-12 schools.

And even when enough computers exist for potentially effective use for small numbers of students, Becker (1985) found that elementary schools with more micros "did not give students any more minutes per week at the computer keyboard--they just extended the opportunity to a larger number of students." ..."Given that the typical elementary 'drill-and-practice' user received less than 20 minutes practice time per week, the primary consequence of using these 'drill-and- practice' programs may have been to acquaint students with a bit of the nature and capacity of computers in the context of showing them how computers might be useful in practicing skills. It is doubtful that they could have made substantial progress in subject-matter learning in this limited amount of time." (p. 13)

Third, while hardware costs account for only eleven percent of total CAI costs (Levin, 1984 p. 17), there is a general assumption that the major investment for schools when implementing CAI is hardware. As a result, once the hardware and limited software have been purchased, few resources remain for other important components of a quality CAI program. Even at that, schools have not been able to purchase sufficient hardware to equip more than one classroom which can be used for CAI purposes at levels which enable improved learning to occur. According to Levin (1984), "The purchase of micro-computers is a necessary condition--but not a sufficient one--for providing CAI services. For every dollar spent on such hardware some four or more dollars of other resources will be needed for the other resources required to provide instructional services such as supporting software, maintenance, personnel, and special facilities." (p. 19)

Fourth, there is the challenge faced by educators as they attempt to utilize one of the most publicized advantages of CAI -- its ability to facilitate individualized instruction. Becker (1985) highlighted these difficulties, noting that "Using computers well is not merely a matter of finding good

software, but of designing a social and instructional system that maximizes the benefits that computers might bring to different types of students facing different educational challenges." (p. 3)

Fifth, extensive time and skills are required to evaluate and implement CAI materials. But schools typically do not support staff training at the levels required to insure proper use of CAI. This results in limited evaluative skills and awareness about how practitioners can make CAI effective. "Because the time and skills needed to conduct thorough evaluations of CAI are not typically available to educators, software evaluation has become education's analog to *Trivial Pursuit*. It largely is devoted to technical considerations, with little more than passing attention to pedagogy and curriculum reform. Whether the software has too much text on the screen or whether it responds properly to incorrect answers is less important than whether it teaches anything worthwhile in a cost-effective manner" (Mojkowski, 1985). Marks (1984), noted that because many teachers don't have the content background necessary to guide their students effectively through the software, too often little or no learning takes place.

Furthermore, the task of evaluating and implementing CAI becomes more complicated and difficult as a function of the sophistication (and to some extent, the quality) of the CAI. Rodrigues (1985) asserted that "To orchestrate this kind of learning environment takes time and effort on a teacher's part. The best products are frequently difficult to learn and differentiate from one another." (p. 25) At least one effect of weak implementation seems to be appearing as students' initial enthusiasm about learning on computers begins to decline. As an example, Kenney (1985) reported that a study of children's attitudes toward computers found that, "The typical student views computers as another 'academic drudgery' and views peers who like the machines as unusually bright or unpopular."

Sixth, very few the CAI programs that are designed for use in the schools are portable (i.e., capable of being implemented on more than one type of computer), they are not designed for networked environments (i.e., single copies can't be operated simultaneously on more than one computer), and they are designed to teach a very limited number of objectives to a very carefully defined audience. The combination of these factors requires school personnel to spend much larger sums of money on CAI software than would be necessary if the programs were portable, networkable, and capable of being used to teach more than just a few objectives.

Finally, it is difficult to guess what the cost/effect ratios of alternative strategies might be. For example, the nature of most well designed CAI requires that instructional objectives are well thought out, that careful task analysis leads to appropriate sequencing, and that all instruction is related to the objectives. But research shows that student achievement improves when objectives are clearly specified and instruction is designed to teach to those objectives in any case. Perhaps some of the benefits associated with CAI (as measured by the effectiveness studies) occurs because, with good CAI, careful instructional design principles typically are followed. If that is the case, increased support to the teachers, to encourage and sustain attention to good instructional design in the planning and conduct of lessons, may improve instruction in the absence of CAI.

The Need to be Cost Effective

The idea that schools do not implement effectively CAI is widely accepted. However, in a climate of increased political and economic accountability, the pressures to demonstrate wise use of educational

resources are increasing. If the return on investment is not demonstrated for educational computing, once the initial attractiveness of the technology wears off, schools will be hard pressed to acquire additional dollars for the technology--regardless of its application. As Mojkowski (1985) noted, "certainly school boards are not going to invest money in hardware, software, and training... without calling on teachers and administrators to show that computers have improved student performance." Even Dalgaard et al. (1984), who reported a reduction in instructional time of thirty to ninety percent, a higher achievement of thirteen percentile points, and higher attitudes toward computers when students were instructed with CAI, asserted "... one needs additional cost information in order to make truly rational decisions in the use of CAI." (p. 315)

Unfortunately the extant research reports on CAI generally avoid cost issues. To illustrate the typical presentation of research on CAI consider the research of Way (1984). In his study, Way reported significant differences in achievement at all grade levels for students who used CAI in laboratory settings. But information was not provided regarding costs, number of work stations, amount of time students spent working CAI lessons, nor the type and extent of CAI use.

In contrast, a study which did include cost data was conducted by Levin (1984). Levin compared CAI effectiveness versus increasing instructional time, reducing class size, cross-age peer tutoring, and CAI drill-and-practice. He reported that larger gains were found for peer and adult tutoring than were found for CAI, and these gains were obtained very inexpensively. Levin concluded that it is more cost effective to improve instruction through the development and implementation of peer tutoring programs than through CAI or by increasing the length of time students spend in classes.

The fact that very few studies attempt to address the cost/benefit or cost/effectiveness issues surrounding the acquisition and implementation of CAI makes these studies of limited usefulness to educators who need to be cost accountable. Dalgaard et al. (1984) reported:

> Throughout much of the CAI literature, researchers have focused extraordinary effort on and attempted to verify effectiveness to the almost total neglect of costs. The focus on effectiveness results from the inherent biases of many project developers (and classroom teachers) who often believe that either (a) effectiveness in learning is important at almost any cost, (b) most costs in education are fixed, or (c) all costs include only the cash costs to the department or unit undertaking the project. Furthermore, when costs are considered, they are almost always underestimated. The value of contributed inputs, such as faculty time, central computer time, and other facilities, often are ignored. (pp. 319-320)

Ascertaining exact cost/effectiveness ratios is extremely difficult for at least two reasons. First, many of the costs and benefits associated with CAI are not amenable to quantitative accounting methods (i.e., they cannot be reported in terms of dollars spent or saved or in increased student achievement scores). Costs readily available include expenditures for hardware, software, staff training, facility improvement, operation and support, and supplies. It is more difficult to determine the costs which are associated with time taken by staff and students to learn how to operate hardware and software or to assess how people feel about the use of computers. School district leaders often believe that sufficient benefit can

be obtained (at least on a temporary basis) by providing their students "hands-on" experiences with new technologies, and that these benefits warrant district expenditures on hardware. Compliance with state laws and regulations and expectations from the local community also justifies certain expenditures.

There is some hope that, as the price of hardware continues to decline, CAI will soon become practical and affordable. But since the majority of the cost of CAI will remain even if the hardware were to be given to schools and since most other costs associated with CAI will continue to increase, much greater investments (or significantly different strategies) will have to be found in order to pursue expanded use of CAI realistically.

Alternatives to CAI

Another use of computers in K-12 environments which can produce measurable benefits without requiring extensive software libraries and large investments in computers, involves using the computer as a tool to help teachers and administrators manage the vast amounts of information required to improve the decision-making process which surrounds instruction and instructional programs. Mojkowski (1985) suggested that "Productivity gains made in employing even the most advanced instructional systems pale when compared with the benefits possible through using the computer as a tool to process and communicate information." (p. 18) This application can provide a practical base for educational computing while building support mechanisms for subsequent implementation of CAI.

Levine conducted a study of exemplary corporations and schools in 1984 and reported that in the best organizations leadership, organizational structure, values, and goals are all directed toward empowering people. But while such use is becoming commonplace in industry, it has not yet caught on in education. Valdez (1986) noted that even though there are large numbers of computers in the schools, educators have not demonstrated the many ways technology can make a teacher's job easier and more rewarding by increasing the educational performance of students. According to Pogrow (1983), this has been due to the dual obstacles of cost and lack of technical expertise on the part of many school administrators. But at present prices, Pogrow asserts that it is a worthwhile tradeoff to purchase personal computer stations to reduce the general paperwork burden that inhibits productivity.

These observations become especially significant when one considers that Darling-Hammond (1984) found in a national study that the best teachers are leaving the profession not due to low salaries but due to lack of "support--physical support in terms of adequate facilities and materials; support services such as clerical help for typing, duplicating, and paperwork chores; and administrative support that would provide a school environment in which their work is valued and supported rather than obstructed by interruptions and a proliferation of non-teaching tasks." (pp. 11-12) By exploring how computers are utilized in the business world, one can see that computer technology can help alleviate these concerns.

In her study of exemplary organizations, Levine concluded "Perhaps the most vital insight that can be transferred from well-run companies to schools is that the success of the organization depends upon creating conditions that will increase the effectiveness of the people in the organization...Schools that have tried to teacher-proof their curricula and their instructional systems and that have removed more and more authority

and decision-making power from the teacher are heading in exactly the wrong direction. What is required are policies and environments that will attract people who want to be valued for their efforts and their effectiveness." (p. 58)

Turkle (Rhodes, 1986b) argued that the best investment on educational computing could be achieved by giving computers to teachers first to use them to help manage student records, calculate student grades, and compile reports. Computer technology offers a myriad of possibilities to increase educators' ability to handle instructional information. For example, integrated software which links the functions of word processing, spreadsheets, data management, graphics production, and communication permits teachers to build, modify, manipulate, store textual and numeric data and transfer that data between functions. With such technology, relevant data which is important to aid planning and evaluation can be shared with other teachers, supervisors, counselors, parents, and students. Records kept in this fashion are readily accessible, easily modified, and require minimal storage space.

Computers can be used to construct domains of test items for easy production of alternate versions of tests. Student performance can then be reported in terms of domain or norm referenced data. Built-in item analysis capabilities enable the validity and reliability of test questions to be examined and, therefore, encourage the development of better progress and achievement tests. Curricula and policy manuals can be stored in databases to enable appropriate and relevant relationships between classroom activities and goals of the school to be determined and kept up to

After the teachers have learned to use the machines to increase their productivity and reduce time required to perform the mundane, technical aspects of their jobs, students should be introduced to the computers, not initially for CAI applications, but, rather, for tools to increase their productivity (e.g., word processors, database managers, graphics generators, spreadsheets, and communication software).

Summary

Until more research can be completed, better software is developed, and CAI is incorporated as an integral part of an overall support system for teachers and administrators, educators will be hard pressed to demonstrate cost effectiveness of CAI. On the other hand, increased productivity can be more easily demonstrated for educational computing when used by administrators, teachers, and students for information management applications assuming that better decision-making can and will occur with the aid of information that is more relevant, more complete, and more timely than can be had without such technologies.

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SELECTED RESEARCH ON COMPUTER-ASSISTED IN READING

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Microcomputer applications in the classroom provide potential for improving instructional effectiveness in the nation's schools. This position is currently held by both the general public and many educators. Due to the limited history of microcomputers in the educational setting, documented support has yet to be firmly established.

Computer-assisted instruction (CAI) was first implemented in higher education on an experimental basis during the late fifties and gradually entered the public schools (Chambers & Bork, 1980; Walker, 1980). Goodlad, O'Toole and Tyler (1966) estimated that only 300 secondary schools incorporated CAI in the early 1960's. In 1964, under the guidance of Stanford University and IBM, the first computer-based reading program was implemented at the Brentwood Elementary School in East Palo Alto, California (Blanchard, 1980). It was not until the late 1960's that technology introduced the silicon chip which led to the development of the microcomputer. The Commodore PET microcomputer was first introduced in the nation's schools in 1977 (Shalaway, 1980). Thus, microcomputers have been in the educational setting for just a decade.

Despite their recent appearance in the schools, the popularity of microcomputers has continued to increase at an astounding rate. The National Science Foundation estimated that there were as many as 200,000 computers in use in the elementary and secondary schools during 1981 (Gleason, 1981). By 1983, Bergheim and Chin (1984) reported that approximately 86% of the nation's school districts were using computers. Becker's (1986) latest national survey of instructional computers found that 86% of the nation's schools had at least one microcomputer devoted to instruction; 24% had 15 or more microcomputers. Although computers are being used more and more in schools for reading instruction, numerous applications of computers for the improvement of learning have yet to be realized. As educators are faced with increasing numbers of computers in the classroom, the need for empirical research on computer-assisted instruction and reading is crucial.

Reviews of the literature focusing on CAI and reading only recently have become available (Marsh, 1983; Mason, Blanchard, & Daniel, 1983). Of the available research, three main categories appear to be relevant to the development of CAI in reading: comparative research on CAI and reading, the effectiveness of various applications of CAI, and CAI as a supplement to teacher directed instruction. The salient studies in each category are summarized in this paper.

Comparative Research on CAI and Reading

The effect of CAI on reading achievement scores and whether the computer provided an effective teaching method have been examined by a number of investigators. One well-documented comparative study was an evaluation of the Stanford CAI Program in Initial Reading (Fletcher & Atkinson, 1976). This investigation was conducted to evaluate the Stanford curriculum, compare sex differences in the use of CAI, and evaluate initial

reading improvement. Subjects were matched on the basis of the Metropolitan Readiness Test, forming 22 pairs of first-grade boys and 22 pairs of first-grade girls who were placed in an experimental and control group. The authors acknowledged limitations of a matched-pairs design; however, this design was selected due to economic constraints. An effort was made to draw students from comparable classrooms which teachers thought to be of equivalent ability. Experimental and control groups were considered comparable in that the experimental group differed only by receiving 8 to 10 minutes of phonics-oriented CAI instruction per school day. During the 5.5-month study, all other classroom activities in both the experimental and control groups were similar. The phonics-oriented CAI curriculum was clearly delineated. Results of the posttest scores on the Stanford Achievement Test, the California Cooperative Primary Test (COOP), and the CAI Reading Project Test indicated significant differences ($p < .01$) in favor of CAI reading subjects. The COOP for matched pairs of girls was the only posttest comparison which failed to indicate a significant difference favoring CAI. Computer-assisted subjects improved their grade placement from 0.4 to 0.7 school years. It was also found that both sexes benefited from CAI, with CAI being more effective for boys. The authors concluded that given such a substantial difference in favor of CAI during such a short period of time, extended use of CAI may well demonstrate dramatic effects.

In a second example, a drill and practice CAI program in reading was compared to a Title I program by Lysiak, Wallace, and Evans (1976). This large-scale investigation took place in Fort Worth, Texas, and included eight elementary and four middle schools. A total of 2298 students in grades three through nine participated in the study. Experimental subjects were removed from their normal reading class to receive 10 minutes of CAI reading instruction per day. Control subjects were also removed from regular reading classes for an unknown length of time to receive reading instruction from a resource teacher. A pretest-posttest design was used to determine achievement gains. Instrumentation consisted of the Iowa Test of Basic Skills and the Gates-MacGinitie Reading Test. Computer-assisted instruction was more effective than the resource teacher, but only for third-grade students. The resource teacher was more effective for fourth- and fifth-grade students. No significant differences were found with middle school subjects, although the middle school CAI subjects experienced a one-month gain in reading over the control group.

A study by the Martha Holder Jennings Foundation (1978) was conducted to determine if the use of CAI would increase reading skills and knowledge, develop positive attitudes toward learning, increase learner productivity, and produce computer-literate students. Using the same students for both the CAI treatment group and the non-CAI control group, 100 sixth-grade students participated in the study. The treatment group received 10 minutes of CAI reading instruction daily for two months. Pre- and posttest scores revealed a 2.4 month gain in reading proficiency after exposure to the treatment. The same students then received non-CAI reading instruction for an additional two-month period. Data regarding statistical significance and actual gains during this two-month period were not reported. It was concluded that students experienced greater gains in reading proficiency during the CAI reading treatment than during the non-CAI time period.

Silfen and Howes (1984) compared teacher-based instruction (TBI) with CAI to determine differences in students' attitudes, time on task, motivation, and skill mastery in reading. One hundred fifty-seven students in grades one through six participated in the four-week summer project. One

group of students received TBI only, while the second group received both CAI and TBI. Both groups received instruction including the essential reading objectives as stated in the Texas Assessment of Basic Skills test. Students in the CAI/TBI group worked in pairs and received instruction via drill and practice and tutorial software for 20 minutes per day. Positive attitudes held by students prior to the initiation of the program dropped, with the attitudes of the TBI group dropping substantially lower than the CAI/TBI group. Regarding time on task, students in the CAI/TBI group tended to be more task oriented than the TBI group. Results also indicated CAI/TBI students were more task oriented during TBI than the students who received TBI only. This finding was interpreted to mean student time on task transferred to regular classroom instruction time. Students who received CAI/TBI had a higher percentage of skill mastery then did the TBI group. However, specific gains and their statistical significance were not reported.

Research in the area of CAI not only has compared CAI to traditional instruction, but also has included various types of instructional methods. A study by Gerrell and Mason (1983) focused on computer-controlled text in comparison to standard print. The purpose of the investigation was to examine the impact of presenting chunked text on paper or via the cathode ray tube (CRT) on reading performance. Chunked text was defined as thought units or the largest unit of meaningful information. Subjects consisted of 30 fifth-grade students from rural Georgia. Results showed that although comprehension was better via computer-displayed chunked text than through the traditional mode, the use of the CRT made no difference in the subjects performance. It was found that chunked text was superior to traditional text regardless of the mode of presentation.

This first set of studies included comparative methods in reading, and results indicated a significant difference in reading improvement in favor of CAI. An overview of the research revealed reading variables were often vaguely defined, leaving the reader unable to determine specific content. It is also important to note that traditional instruction most likely varied from study to study. Therefore, the assumption that CAI is superior to traditional reading instruction must be made with caution.

Effectiveness of Various uses of CAI

Rather than attempting to determine the effectiveness of CAI versus non-CAI reading programs, a number of investigators have examined the effectiveness of various uses of the computer itself. The effects of repeated reading via computer presentation were examined by Carver and Hoffman (1981). The purpose of this study was to examine increases in reading rates, decreases in reading errors, the degree of skill transfer to new material, and the effect of repeated readings on general reading ability. Two separate experiments were conducted, the second being a replication of the first. Six high school students identified as poor readers participated in each study. The sample size was small due to the expense of the computer hardware and to the fact that only one student at a time was able to receive reading training. Treatment procedures included a two-hour training session three days a week for four months. A computer program entitled Programmed Prose was developed specifically for the study. A total of 80 passages tested for readability comprised the reading material. The authors provided a detailed account of the program itself along with a sample passage. Students progressed through the 80 passages rereading for accuracy. The findings indicated an increase in fluency as a result of repeated reading practice. Test results also suggested that when a similar type of

performance was required, training transferred to new materials. The researchers stated that only partial support was obtained concerning the proposition that gains in reading fluency would transfer to general reading ability.

Reinking and Schreiner (1985) examined the use of the computer to mediate text according to individual needs and to monitor and assist readers experiencing comprehension difficulties. The researchers hypothesized that providing readers with the opportunity to overtly interact with the text would augment active text processing. The subjects consisted of 104 fifth- and sixth-grade students who were randomly assigned to either the control group or to one of three treatment groups. Each subject was identified as either a good or poor reader. The subjects met once a week for three consecutive weeks and either requested or were provided with the following text manipulation options: definitions of key vocabulary, a less complicated version of the text, supplemental background information, and presentation of the main idea of the passage. All groups read six expository passages identified as having either high-or low-difficulty levels. The control group did not use the computer, nor was it offered the text manipulation options. Treatment 1 read via the computer but did not have text manipulation options. Treatment 2 had access to both the computer and the text manipulation options. Text options were mandated through the computer program for Treatment 3. Data analysis indicated students scored significantly higher on comprehension when the computer controlled the text options. The investigators concluded that controlling text options with the computer was more effective than allowing students the option of selecting additional help.

In a similar study, Carrier, Davidson, Williams, and Kalweit (1986) examined the effect of program-generated encouragement on the selection of text elaborations. The investigators hypothesized that learners with external locus of control would be less likely to choose instructional elaborations, while learners with internal locus of control would be more likely to select the elaborations. Thirty-seven sixth-grade students were divided into two computer-based treatment groups. Both groups were provided with an option to view instructional elaborations such as: a paraphrased version of the concept definition, exposure to an additional expository instance, analytical feedback, additional practice, and analytical feedback on the additional practice instances. The groups differed in that one group received program-generated encouragement to select the text elaborations, while the other group did not receive computer encouragement. Results indicated subjects receiving computer encouragement selected more options than those who did not receive encouragement. The tendency to select options appeared to function independently of locus of control.

CAI as a Supplement to Teacher led Instruction

Lally (1981) suggested that the computer be used as an adjunct to the usual teaching environment to provide new methods for students with learning difficulties. The purpose of the study was to determine if knowledge gained from CAI could be applied in a classroom setting. Sixteen subjects aged 9 to 16 years with a mean IQ of 60 were placed in one of two groups matched for age, IQ, and initial sight vocabulary acquisition. The training group received 20-minute sessions four times a week for four weeks for a total of five hours of computerized sight word recognition instruction. Training sessions consisted of direct interaction between the learner and

the computer. All instructions were "spoken" by the computer and consisted of two phases. During Phase I, students chose sight words while the computer responded by pronouncing the corresponding word.

In Phase II, the computer chose the sight words and instructed students to press matching keyboard letters. A correct response elicited computer pronunciation of the word. Although the instrumentation was not identified, assessment sessions took place prior to training, immediately after and at 4-, 8-, 16-, and 23-week intervals following the end of training. Sight word recognition increased in the training group from 27% to 211%, while the comparison group improved from 0% to 71%. The increase of the training group did not decline over an 18-week period. Despite the increase in sight word recognition, the improvement did not transfer to general reading ability. The author suggested an extended training period would allow students to transfer skills. It was concluded that CAI can serve as an adjunct aid to classroom teachers.

The relationship between teacher computer usage and students' reading achievement scores was investigated by Schaudt (1985). The researcher hypothesized that the use of CAI as part of a direct instruction lesson could explain in part the variance in student reading achievement scores. A sample of 66 elementary classroom reading teachers from an east Texas school district participated in the study. Each classroom teacher was rated by the Assistant Principal for Curriculum of his/her respective school using a researcher-developed scale. The Assistant Principals for Curriculum received a 1-hour training session concerning the use of the scale. The instrument was designed to identify teachers who use the computer in a direct fashion and those who use it in a non-direct fashion. Direct CAI was defined as the use of computers as an additional material to support a direct instruction reading lesson. Direct instruction was defined as lessons which have an academic focus, are teacher-directed, have goals that are made clear to students, in which sufficient time is allocated for teaching, and during which the teacher monitors student performance. Non-direct CAI was defined as the use of computers in a center, free-time, or reward activity, including any form of use outside a direct instruction reading lesson.

The results of the study did not support the hypothesis. However, significant findings at the $p < .01$ level suggested that primary teachers use direct CAI more than intermediate teachers and that they allocate more time to CAI and reading than do intermediate teachers. Also significant at the $p < .01$ level was the finding that those primary teachers who used direct CAI and allocated more time to CAI in reading did have students with higher reading achievement scores.

Conclusion

A review of the literature has revealed many research shortcomings in the area of CAI and reading. Instrumentation was not consistently identified, making validity of choice of assessment tools difficult. Many inquiries failed to report the duration of the experiments and/or the amount of time used in CAI treatments. Few reports provided step-by-step procedures enabling replication for the confirmation or rejection of findings. A majority of researchers failed to discuss the possible impact of the quality of the chosen software. Often times the definition of variables was amorphous, limiting generalizations. Unfortunately, the research in CAI and reading appears somewhat less than systematic. Perhaps the most disconcerting finding was the potpourri of investigated areas. However,

many of these shortcomings may be due to the newness of CAI in reading. With the introduction of a new teaching tool, the unanswered questions with which researchers are faced are multitudinous. Each of the aforementioned studies attempted to address one aspect of the many facets of reading. It is evident that our knowledge base is limited. At this point, researchers cannot state with confidence what type of learner will benefit most from CAI in reading, what reading skills may be enhanced through CAI, or how classroom teachers may effectively incorporate CAI in their reading lessons. Computer-assisted instruction in reading presents a virtually untapped area of research.

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COMPUTER APPLICATION IN SECOND LANGUAGE LEARNING

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The development of computer systems has been accompanied by an increase of computer applications for educational purposes, including second language learning. At the present time, leadership in the application of computers in the field of English as a second language rests with the United States, Canada, Great Britain, Denmark, and Japan. As computer technology has been available for educational purposes, its increased use has enhanced the assessment of learner participation in instruction of second languages.

In Denmark, immigrant children who were not fully proficient in Danish received remedial instruction from their teachers; these children improved in Danish after computers were used in second language training for three years. These children reportedly, enjoyed using the computers and competed among themselves to use the machines. (Lyster, Dalgaard & Belhage, 1984).

In another account, computers have been used in Japanese schools, to teach English and other languages. The Japanese Language Academy teaches English directly with an instructor complemented by computer programmed instructional sessions which combine slides and a voice synthesizer. In this application, computer instruction has the important audio dimension of language which is lacking in many computer learning programs. Finally, a student meets with a native speaker of English to reinforce the gains made in English proficiency (Araski, Tanabe, Falt, Johnson, & Hayashi, 1978).

USE OF COMPUTERS IN LANGUAGE LEARNING

Computers have many applications for teachers of English as a Second Language (ESL) at all grade levels. Today, they are used to supplement regular classroom ESL instruction and to provide personalized assistance to individual students. Those computer programs that are used for supplementary instruction provide opportunities for: (a) additional practice; (b) remediation; and (c) enrichment (Larson, 1984a). This application is especially useful for a teacher when some students are at different proficiency levels compared with other children in the class. Those students who are behind their classmates in mastering second language concepts and skills can "catch up" with additional guided practice. However, gifted and talented children who are more advanced than their classmates can increase their proficiency by working with advanced computer lessons. As a result, the more able students sustain a high level of interest for second language learning (Larson, 1984a).

Experience has shown that computers stimulate student interest in improving their proficiency with English. Computer software featuring graphics, color, animation, games, and simulations serve to raise student motivation as well as increase the effectiveness of second language

instruction (Larson, 1984b). Involving the ESL learner in the process of learning can be a motivating factor in the second language acquisition process. For many student learners, ESL instruction focuses on the continued use of textbook coupled with teacher directed instruction. Consequently, little time is allowed for critical thinking, reflection, and/or problem solving; conversely by utilizing computers in the learning process, a student "self-directs" his/her instruction and receives immediate feedback which provides a knowledge base for the assigned task.

Computers also allow for the personalization of ESL instruction. Providing numerous opportunities to practice a target language and receiving immediate assistance in correcting possible errors makes the computer an invaluable tool in the improvement of English proficiency for the learner. However, a computer cannot replace the personal presence of a caring teacher who motivates children and youth (Larson, 1984b). Yet computers can be a valuable instructional supplement to ESL programs when academic skills and language proficiency of the students vary widely, and their teacher has limited professional training and/or expertise in the field of ESL. Teaching students to be more self-directed and responsible for their own learning is an important component of learning with the assistance of computers. Yet, many ESL students will require an orientation to unfamiliar equipment before these instructional applications can be beneficial to them. (Larson, 1984c).

Classroom Application in Second Language Teaching

The primary computer applications in teaching language include Computer Programmed Instruction (CPI), Computer Assisted Instruction (CAI), and Computer Managed Instruction (CMI). Computer Programmed Instruction provides instruction for a learner while teachers assume the role of a facilitator when they are requested to provide assistance. When teachers become facilitators in the learning process, learners, assume greater control of their learning programs. Under these circumstances learners assume some responsibility for their lessons, as well as the pace of instruction (Moursund, 1980).

In contrast, Computer Assisted Instruction (CAI) supplements a classroom teacher's instruction. Applications of CAI do not replace instructional personnel; however, CAI becomes a personalized program of supplementary instruction. This form of educational technology has become useful in the instruction of foreign language (Post, 1981).

Another use of computers in language teaching is Computer Managed Instruction (CMI). This computer application provides management assistance for routine clerical and administrative tasks assigned to a classroom teacher. CMI includes record keeping, scoring tests, tabulating student test scores, data storage and retrieval, and test generation (Moursund, 1980). This application is useful because it allows a classroom teacher more time to spend on other aspects of language instruction. Yet teachers have expressed concern about computer technology replacing them in their instructional role rather than assisting them in the classroom. As a result, this perception has hindered acceptance in the use of computer as an instructional tool in the teaching of second languages (Moursund, 1980).

Computers can be utilized in different ways in teaching second languages. Both CPI and CAI provide drills and exercises that allow a learner to practice their newly acquired linguistic skills. These applications provide a learner with instruction in the form of tutorials. In this format, a

learner is provided with a more detailed set of explanations enabling the student to become more independent (Moursund, 1980).

To illustrate its usefulness, CMI was used by the Connecticut State Department of Education to evaluate bilingual education programs across the state. In this instance, CMI generated information about individual programs in less time than with previous methods resulting in specific program changes being made to correct identified deficiencies in programs (Behuniak, 1985).

New uses of computers in second language instruction have included games and simulations of real life situation in which application and synthesis of knowledge and skills are encouraged. Games and simulations occur in both CAI and CPI applications.

Computer Adaptability

A program can be personalized by modifying the pace, sequence, and level of difficulty for each child's instructional request. This becomes very useful in those classes where pupils have varying levels of English proficiency, which is common in an ESL classroom. Students are capable of judging their own progress or deficiencies with most of the software programs. A computerized program allows them to select the sequence of lessons to review, request remedial assistance; and advance to new material. By using computers as a means of individualizing the student's instructional program, a teacher can create an instructional environment where problem solving and risk-taking become the norm. In this environment the classroom teacher assumes the role of a facilitator who specializes in diagnosing and guiding an ESL student.

Listening and speaking

The listening and speaking skills in second language instruction and learning have been considered as primary factors in the second language acquisition process (Gonzalez, 1984). However, Asher (1977) stressed the necessity for teachers to provide special opportunities for second language learners to develop their listening skills.

New ESL computer programs have voice synthesizers and video-discs to make language instruction more effective. Also, voice-based learning systems have been added as an important audio dimensions to language learning (Larson, 1984b). While an interactive video system uses both audio and visual stimulation, Rietmann (1981) has indicated that the use of audio-visual dimensions of this system allows for computer analysis of a student's ability to pronounce English. Further, there are computer games with voice synthesizers, and several game activities available which can be used to develop the ESL student's listening and speaking abilities (Larson, 1984b). Computers with these periphery devices serve as excellent instructional supplements to enhance the language arts program.

Computer Use in ESL Reading

In the area of ESL, English educators have been exploring new ways to use computers to enhance learning to read English as a second language. Higgins (1984) proposed the use of the computer to promote taking risks in reading comprehension exercises after noting that risk taking is characteristic of efficient readers resulting in their reading at faster rates. He created a computer game entitled "Close Up" which directs ESL students

to predict, takes risks, and guess about what they are reading. A single word is presented on the computer screen, and more words and sentences appear until a student can select from eight titles. Students gain points guessing correctly with a few clues, and lose points by requesting clues. Higgins claims the game increased student interest and motivation due to enjoyment of playing the game.

There is more to reading than just skimming, scanning, and finding the main idea. ESL learners need to understand the process to become a skilled reader. Research indicates that ESL reading is often taught by using books that include collections of interesting activities or stories at the linguistic level of the students (Mikulecky, 1984). Generally reading skills exercises are associated with tasks for lesson completion. Reading skills are not presented in a logical or developmental sequence in these resources, but as a set of necessary skills to master a specific passage. Selecting computer software that stresses reading comprehension as an interactive construction is more beneficial to the ESL reader then mastering isolated reading skills reflected in current resources used in ESL classrooms. Appropriate software should assist the ESL reader to, sample the text, guess the meaning, and confirm the guess through further sampling of the text (Mikulecky, 1984).

Writing with Computers by ESL learners

Writing is a difficult skill to acquire, especially for a second language learner who is trying to master the necessary academic skills being presented in the new language. In order to become proficient in written expression, an ESL learner has to, find an interesting idea, determine its focus, and choose the precise words that will express an idea so that others can comprehend the intended meaning. Writing with computer assistance provides ESL learners with an opportunity to explore with manipulations of the language (Solomon, 1985).

Computers can make a contribution to the instruction of written expression by ESL students. Among the language arts programs available for classroom use are three types of software which are appropriate for writing instruction. These writing skills software assist ESL students to:

(a) reinforce the manipulation of language;
(b) serve as story generators; and
(c) function as idea processors while developing writing skills.

Research indicates that second language instruction should focus on writing communicative competence versus only linguistic competence (Krashen, & Terrell 1983). A variety of approaches including free writing and expansion activities have been suggested for the teaching of writing skills to ESL students (Raimes, 1983).

If ESL classrooms utilize computer programs to enhance the written composition process, the ESL learner will be involved with a process of writing and not become overly concerned with the product and the mechanics of writing. Specifically, computers can provide assistance in the elimination of linguistic deficits and establish a sense of appreciation for the creativeness within the learner and others (May, 1984).

Conclusion

ESL learners need assistance with many language skills which focus on understanding the complex relations between reading, writing, and thinking skills. Utilizing a computer as an instructional tool can integrate the skills

of reading, reasoning, and writing. When integration is accomplished, ESL students are shown that language skills are not separate from one another and become more proficient speakers, writers and thinkers.

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TEACHING THE HANDICAPPED AND DISADVANTAGED VIA COMPUTER: WHAT WE HAVE LEARNED FROM FIELD RESEARCH

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Research studies and developmental projects associated with microcomputers and the handicapped have increased dramatically since funding became available from the National Institute of Handicapped Research (NIHR) and from other federal agencies. These funding agencies support and currently seek projects that exploit the emerging microcomputer technology and that address the mandates of Public Law 94-142 (Federal Register, 1986). Studies resulting from this funding emphasize the innovative use of microcomputer technology for enhancing the quality of instruction, for mediating the teacher to pupil interaction, and for maximizing service. Results indicate that microcomputer research may eventually have significant application for handicapped instruction.

Although the number of studies dealing with microcomputers and the handicapped have increased, there are two serious weaknesses in computer related research. First, the contributions of research benefit only one portion of the handicapped population. Hofmeister and Thorkildsen (1984) estimate that the contributions of electronic devices benefit only 10 percent of the school-aged handicapped; the other 90 percent, constituting the mildly and moderately handicapped, do not benefit from computer applications in either regular or in special education. Second, there are few comprehensive reviews of either related research (Stowitschek & Stowitschek, 1984) or of field developments related to handicapped populations (Hofmeister, 1984). Further, the available reviews tend to emphasize limited aspects of computer technology or to include research completed with normal or gifted children (Katz, 1983). For example, Harrod and Ruggles (1983) review computer assisted instruction; Appell and Hurley (1984) consider computer assisted individual instruction; and Warren, Alpert, and Kaiser (1986) survey computer assisted infant stimulation programs. Consequently, there is a need for a research review that focuses on research and innovative applications for both the profoundly handicapped and the less seriously handicapped if researchers are to develop, to implement, and to evaluate effective research for the handicapped.

The purpose of this article is to provide an overview of research and development activities that utilize the computer to address the unique needs of handicapped and disadvantaged learners. The report is organized into two major divisions: (a) computer applications that make teaching possible by enhancing the learner's ability to control the environment and to communicate, and (b) computer applications that make teaching profitable for both the learner and the teacher. The concept of field research, as formulated by Cook and Campbell (1979), was broadly defined to allow greater flexibility in reporting current research. However, stringent criteria were employed in selecting work to be included in this review. The research

reports met the following criteria: (a) entries were field based, (b) entries represented reports of research or demonstration projects, (c) entries used computers, (d) entries were related to teaching, and (e) entries identified handicapped and/or disadvantaged individuals as the target population.

MAKING TEACHING POSSIBLE: IMPROVING THE QUALITY OF LIFE THROUGH TECHNOLOGY

Research in the area of making teaching possible focuses on advancements that help severely handicapped individuals control their environments and on methods for improving communication capabilities. As evidence for this concern for environmental and communicative needs, six of the top ten awards in the Johns Hopkins Search were for devices to manipulate and control the environment and to enhance communication. Typical research in this area is reflected in the Montana Assistive Technology Project (Stowitschek & Lukenbill, 1986) which proposes to bring technological advances in the area of mobility, environmental control, and communication to low incidence populations in rural settings.

Controlling the Environment

Normal individuals take for granted the simple acts of controlling the environment, such as turning on a light switch or making a cup of coffee. Lack of such environmental control is an extreme barrier for some handicapped individuals; thus in 1980, researchers at Johns Hopkins University undertook the First National Search for Applications of Personal Computing to Aid the Handicapped. This year-long search offered nearly 150 cash awards and prizes in the first nationwide attempt to find creative software and hardware applications for special needs individuals (Schiffman, Tobin, & Buchanan, 1982). Two of the top ten awards (i.e., second prize and honorable mention) were given for the "Eye-Tracker" input device and for the "Ultra-sonic head control for a wheelchair" ("Personal Computers," 1982). The "Eye-Tracker" utilizes eye movement infrared photography and allows a person to cause a word or phrase to become audible by looking at it on a computer screen. The "Ultra-sonic head control for a wheelchair employs ultrasound distance ranging technology to enable a quadriplegic in a wheelchair independent mobility. Both of these devices are in use today and have uniquely broadened the horizons of their users.

Mittler (1985) describes current research and applications of the robot in special education including the robot's ability to control the environment, to use synthesized speech, to respond to voice commands, to provide reinforcement, to interact with socially limited pupils, and to assist in daily living activities. Mittler's enthusiastic report sounds like science fiction coming true for the handicapped.

On-going research at George Mason University in Fairfax, Virginia., teaches severely handicapped infants and toddlers (babies between 11 and 30 months old) to use the microcomputer for environmental control (Behrmann, 1984; Collins, 1986; Lahm & Behrmann, 1985). Initial training establishes simple cause-effect relationships: pressing a switch makes a happy face appear on the monitor. The switch may be activated by hand, head, foot, or even eyebrow. The next level of training requires that the babies learn to discriminate between two possible choices: turning on a radio or activating a mechanical toy. The third level is a game of matching a

stimulus picture to one of two possible choices on the microcomputer. Correct matches result in a reward (operate the toy or radio).

The fourth level of Behrmann and colleagues' training program offers more choices, and the baby receives a verbal prompt and encouragement from the computer's voice synthesizer or the teacher. At this more abstract level, the baby must associate a verbal symbol (the prompt) with the picture on the computer screen. Also there are about 12 options offered at this level which expand the number of possible ways that the baby may interact with the environment. The fifth and sixth levels of training give four more options and introduce the concept of categorization. The final outcome for the training is that the babies become able to manipulate a small maneuverable robot to bring toys and objects to them and to signal for help when needed. As a result of this training, profoundly handicapped babies will eventually be able to control or manipulate at least a part of their surroundings.

Controlling Communication

A review of the Johns Hopkins Search report shows that 22 of the 97 best entries dealt with nonvocal communication (Schiffman, Tobin, & Buchanan, 1982), and the first prize was awarded for a Portable Telecommunicator for the Deaf. This device is a pocket-sized word processor designed to help a speech impaired individual communicate with others via the common telephone. Third prize was a "Lip-reader Trainer" which converted typed sentences into animated mouth movements to provide the deaf person with practice in lip-reading. Although not an award winner, the talking wheelchair provides a "Versatile Portable Speech Prosthesis" which may be used to control the battery powered wheelchair or to communicate with others via the voice synthesizer (Deane, 1982).

O'Connor (1986) discusses research that investigated vocabulary learning and use, motivation behaviors, and social and communication growth of eight severely handicapped toddlers. Language intervention conditions included either a computer based approach or a traditional intervention technique. Significant changes in social skills and communication were evident for the computer based approach.

Meyers (1984) describes the use of microcomputers in language stimulation therapy with a severely handicapped child. The child was 26 months old, blind, nonvocal, and cerebral palsied. His parents reported that he enjoyed being sung to, so this was used as the initial treatment effect. Mother began singing a song and, after a short while, would stop singing and question the baby, "Do you want me to sing?" Any positive response by the baby was accepted and mother would again sing. Response requirements on the child were gradually increased, using verbal prompts and guiding his hand until he could unassisted hold his hand on the keyboard and activate the input switch. Now when mother sang, stopped, and questioned, the baby responded by touching the keyboard, smiling, and anticipating the next song. The voice synthesizer would produce the word "sing" and mother would sing again. On several occasions the baby said what appeared to be the word "sing." Later this response foundation was used to teach the baby how to request food and his favorite toy. Through the gradual increase in the child's response repertoire, he was able to initiate control over his most immediate environment and to acquire a few identifiable sounds and words.

Research has also been conducted using less severely handicapped children. For example, Nelson (1985) discusses research involving teaching American Sign Language to deaf children who are three to ten years old. The system builds in perceptual salience, specialized vocabulary, and animation

of color pictures and the graphic representations of signs. The learning mechanism underlying this novel communication system is best characterized as interactive and exploratory. Nelson reports significant improvement in reading and writing by the deaf children after a relatively short time with the program. This program may be successful because it is reflective of the way in which most children acquire a first language.

Computer Aided Speech Production and Training (CASPT) is a program which provides quality speech production without hours of repetition required in programs based on human modeling of correct speech. In fact, the motivational factor of this computer-assisted learning activity produces a situation that could provide almost unlimited repetition of a trained sound with a minimum of assistance required by the speech clinician or teacher (Nielsen & Cooper, 1986).

The above examples of applications of computers to assist in control of the environment and in communication indicate the potential for improving the quality of life of severely, profoundly, moderately, and mildly handicapped children. Personal control of one's environment and the ability to communicate, even when these functions must be assisted in some way, open new pathways to learning for the handicapped and present exciting new challenges to the practitioner.

MAKING TEACHING PROFITABLE: IMPROVING THE QUALITY OF EDUCATION THROUGH TECHNOLOGY

Making teaching profitable implies that both the teacher and the learner can benefit from using computers to directly and indirectly improve instruction and learning. This section draws implications from research and demonstration efforts that attempt to improve the quality of education for the handicapped.

Preparing for Instruction

Computer-aided education (CAE) concerns those aspects of the teaching function that are inextricably woven into the fabric of all instruction. Such functions include: (a) providing formal and informal assessment of pupils for placement and instructional decisions; (b) selecting the best available instructional materials including software; and (c) developing lesson plans, managing groups, and creating individual educational plans (IEP). Each of these functions can be improved with the aid of the computer and adequate software.

Assessing Handicapped Pupils

Prior to the widespread use of the microcomputer for such purposes, the large mainframe computer was used in computer managed instruction (CMI) to train diagnosticians, psychometrists, and other assessment personnel in the careful analysis and interpretation of information obtained from standardized individual psychological tests and curriculum based tests (Anderson, 1972). Venezky, Bernard, Chicone and Leslie (1975) introduced a computerized diagnostic reading system connected to the PLATO network, and subsequently Hines and Warren (1978) produced cloze tests for reading diagnostics. Although these early efforts demonstrated the feasibility and utility of computer assisted diagnostics, the use of the larger computer was very expensive. The microcomputer brought lower costs and more

adventuresome efforts to capitalize on the unique capabilities of the computer to meet assessment needs.

One example of the more recent uses of the microcomputer in assisting teachers is offered by McCann (1986). A Computerized Behavior Assessment and Programming System (CBAPS) was developed to provide an adaptable framework in three major areas: (a) to assess pupil performance in over 100 learning and social skills; (b) to review empirically validated interventions for each target skill; and (c) to plan, implement, and evaluate behavior change programs. CBAPS includes a computerized behavior graphing system with which students or teachers monitor pupil progress toward attainment of behavioral goals. McCann reports that field testing in two regular and two special education classrooms has demonstrated that CBAPS increases pupil performance of target behaviors, and improves teacher knowledge and use of suggested interventions.

A much-needed breakthrough for data-based instruction was reported by Evans (1986). He describes how a wireless microphone system coupled with a Voice Input Module and Apple IIe computer is used to unobtrusively enter behavioral data during the normal operation of the classroom. All recordkeeping, analysis, and reports are completed by the system while the class proceeds normally.

Selecting Instructional Materials

Evaluation and selection of textbooks and instructional materials have long been a cornerstone of teaching. The quality and care given to this task reaps dividends during the actual presentation of a lesson and the evaluation of instructional objectives. Selection of appropriate materials for computer assisted instruction demands the same care and concern for quality as given in evaluation of other instructional materials. That is, the material should be evaluated statically (i.e., by the reviewer) and dynamically (i.e, by the student who will ultimately use it) (Hickman & Anderson, 1979). Unfortunately, the range of possible software is exceedingly limited when compared to the range of textbooks and other instructional materials.

Two concerns for selection of software have plagued special educators since computers were first introduced in the schools: the best selections were too expensive, the cheaper selections were not worth the price. Although quality of instructional software continues to be a major issue in instructing both handicapped and nonhandicapped learners, some improvements can be noted. Unfortunately, many pedagogically unsound examples of software remain on the market. With the continuing "no preview" restriction on most educational software, teachers and others must select materials blindly. Unlike textbooks and other print materials, software is not typically returnable for refund after opening.

The general lack of quality software is one of the major detriments to effective integration of the microcomputer into special education classrooms. This concern has led several state departments of education to issue guidelines and other edicts for software selection and use. As a consequence, five states have formed a national consortium of projects concerned with technology for the handicapped including a clearinghouse of software which requires a common software evaluation instrument and coordination of all software purchases, evaluations, and reviews (Allard, 1985). Thus the quality of available software is improving, but the process is slow and often impeded by the lack of access to the software prior to purchase.

Lesson Planning, Grouping, and the IEP

Several computer software programs have been developed to generate lesson plans and instructional activities that are correlated with the pupils' IEPs and existing curricula (Hammerbacher & Simon, 1985). For example, the ASSIST authoring program for lesson planning has been demonstrated to be effective when used with 200 mildly handicapped pupils attending four elementary and four junior high schools (Chiang, 1978). The SPE.ED authoring system (Zuckerman, 1986) provides the same type of assistance to special education teachers.

A more sophisticated program, AIMSTAR, is actually a set of integrated computer programs designed to help teachers implement the decision-rule process in the classroom (Hasselbring & Hamlett, 1982). AIMSTAR lets teachers develop detailed IEPs, manage pupil reference data, and implement data-based decision rules. The program produces graphs and monthly summary reports on pupil progress.

An integrated software program has recently become available which addresses the true management function of the special education teacher. Not only does the software system allow building-level personnel to print an individual educational program (IEP) but the software system tracks individual due process requirements also can create and recreate very effective instructional groupings based on information about achievement, IEPs, and other factors. This program was developed in conjunction with the Maryland State Department of Education and was selected as a national model training and exchange program through the Council of Administrators of Special Education (Miller, 1986).

PRESENTING INSTRUCTION

This second part of Making Teaching Profitable discusses field research and developmental activities designed for implementing computer assisted instruction and related programs. Each of the researchers explains that instructional, contextual, and interpersonal variables influence computer based instruction in special education settings, yet few of them controlled for all variables. Favorable results were typically reported however. The content of the computer software and other programs designed for the learner's direct use, suggests three organizational topics: (a) the instructional use of "general use" programs such as word processing or electronic spreadsheets; (b) the instructional use of specific courseware or computer assisted instruction (CAI) material; and (c) the recent instructional use of interactive video. Each of the three organizational topics represents efforts to utilize the computer to help learners help themselves, that is, to provide an instructional program that is used directly by learners.

General-use Programs

Several programs which were designed for general use, or in some cases for business use, have been adopted as classroom software. These general-use software programs differ from computer assisted instruction (CAI) software on several accounts. Primarily, the utility of each general use software in addressing multiple content areas distinguishes these programs from CAI programs which tend to be subject matter or content specific. Examples of general use software commonly used by pupils are LOGO,

various types of text editors and word processors, and in some cases electronic spreadsheets.

Logo has been particularly successful with mildly handicapped pupils because LOGO activities stress problem solving rather than right and wrong answers. The pupils realize very early in learning LOGO that it is the process involved in using LOGO that counts, not the product completed (Chiang, Thorpe, & Lubke, 1984). (For handicapped children, however, a great deal of pride is often expressed with the product.) One federally funded project that investigated the effect of LOGO instructional software versus teacher directed activities (the control) on 700 pupils, ages 3 to 11, was reported by Harckham and Ferber (1986). General cognitive skills were assessed in relation to LOGO achievement using Vygotsky's model of concept formation. Results demonstrated that LOGO was an effective treatment for improving overall classroom behavior, general cognitive ability and problem solving skills.

There are numerous studies reporting the use of various types of word processors and text editors to facilitate instruction of handicapped pupils. For example Kleiman and Humphrey (1982) reported that learning disabled children, from age 7 to 16, enthusiastically increased their writing products when encouraged to use the computer and word processing software. Rubenstein and Rollins (1978) developed a letter writing project with 40 deaf pupils who had previously been identified as reluctant writers. Over the course of a year with computers and appropriate word processing software, the pupils wrote over 1500 letters to each other.

Use of several types of text editors has also been reported with favorable results. Morocco (1985) reported an intensive eight-month observational study of 15 learning disabled pupils. She summarized preliminary findings in terms of teaching strategies used when either introducing the text editor, or assessing children's writing as they used text editors. In addition, she focused on the impact of the text editor on the development of both process and product.

Bank Street Writer is often cited as the most desirable word processor to use with pupils (Hill, 1985). One study (Bazarnik, Ward, & Bazarnik, 1986) examined pupil use of the Bank Street Writer software in developing and improving writing skills. Teachers implemented a process approach to writing which included use of the word processor and conferencing to simulate the author to editor relationship. Results showed improved writing ability, greater initiative, increased attending to tasks behavior, and task completion, greater independence and socialization skills for these severely language impaired students.

A Bell Laboratory program, Writer's Workbench, analyzes a student's writing and compares the writing with models entered by the instructor. The computer prints lists of suggestions on how to improve and rewrite the essay to more closely match characteristics of the model. This program lets the teacher read for content while the computer edits the early drafts.

Computer Assisted Instruction Courseware

There is a proliferation of research and development activities utilizing CAI materials to enhance the learning of handicapped and deprived pupils. This discussion stresses CAI in language arts, in mathematics, and in non-content but related areas.

Computer assisted instruction has been investigated as an aid to improving all of the language arts. Reports have noted improved pupil compositions through responses to computer generated questions (Burns &

Culp, 1980); through sentence combining (Bradley, 1982); and through prompts, sentence openers, and spelling checkers (Woodruff, Bereiter and Scardamalia, 1981). Norton (1985) reviewed research on computer applications in language arts and reported three studies yielding dramatic pupil gains: (a) a program that taught reference skills to disadvantaged sixth-grade children, (b) a program that taught sound-letter correspondence to improve spelling ability and sight word knowledge of second graders, and (c) a program for speakers of other languages to learn English using a voice synthesizer on a computer.

Lally (1981) reported a study on the effectiveness of the computer in teaching sight word recognition to 8 mildly handicapped pupils. Results indicated that the CAI group increased the number of sight words recognized from 38 to 70, while the control group increased from 38 to 47. After a 7-week interval the CAI group retained all 70 of the recognized words. The same degree of improvement was reported for spelling remediation with learning disabled and mildly mentally retarded pupils. In fact, Donovan and Zimmerman (1986) stress that computer assisted spelling remediation produces the same or better results as teacher-guided spelling instruction.

One exciting approach to language arts instruction is the "Writing to Read" Program (Kirkland, 1985). Writing to Read was originally designed for use with kindergarten, first, and second grade children, but is adapted to meet the unique needs of pupils with communication and reading problems and pupils with learning and physical disabilities. The total Write to Read system is based on the philosophy that children will learn to read more effectively if they are taught to write, (i.e., to encode their normal speech as an initial process in learning to read). This program develops the skills required to be successful writers and readers in the primary grades. The computer is programmed to teach the children the phonemic constituents of English, not only those related to the 26 letters of the alphabet, but also the 42 sounds of English which have been identified and are represented in 500 different ways. The program also teaches how to combine sounds and letters to create words. Other activities are provided to reinforce the computer instruction so that pupils can write and read their own stories and those written by others. Results from the numerous sites which have field tested the program are positive and highly optimistic.

Computer assisted instruction in mathematics, especially in drill and practice format, has traditionally been used with highly favorable results. Watkins and Webb (1981) compared the pretest and posttest mathematics scores of two groups of learning disabled pupils. The experimental group received CAI, the control group did not. The CAI pupils achieved significantly greater gains than the traditionally instructed group. Trifiletti's (1982) work is similar in that the CAI group gained about twice as many skills as the control group during the first five months of the program and achieved a mean of eight months academic gain compared to the control group's gain of only three months over the full academic year.

Other research interests have been investigated including promoting positive social interaction with peers through selected computer programs (McCann, 1985), effective learning in groups using the computer (Robinson, 1986), and interviewing techniques to ascertain pupils' and others' perceptions of the computer's effect on learning (Okolo, 1986). A few investigations report no academic gains following the use of the computer and CAI, but almost all report gains in task commitment and time-on-task (Anderson & Cross, 1984). For example, McDermott and Watkins (1983) found no difference in effectiveness of CAI programs when compared to

conventional methods. Several plausible explanations are usually presented to justify this unusual finding.

The study reported by Kleiman, Humphrey, and Lindsay (1981) is particularly relevant here. They investigated the effects of CAI on the problem solving of 18 children described as hyperactive. On alternate days, pupils worked on the computer and with paper and pencil. Performance was compared between the use of these two mediums on accuracy, problems attempted, and speed of problem solving. The only real differences between the two methods were in (a) number of problems attempted and (b) time commitment. That is, the pupils attempted almost twice as many problems on the computer and spent almost twice as much time working on the computer, but there was no difference in accuracy or speed of problem solving. The authors concluded that the computer seemed to be highly motivating and seemed to increase attention span or at least time-on-task, but the computerized approach did not seem to affect learning.

Interactive Video

Another very exciting development in utilizing the computer for teaching mentally retarded and communicatively disabled adolescents is the successful use of interactive video as a learning medium. One early effort linked an optical video disk and a computer (Thorkildsen, Bickel & Williams, 1979); another linked a Kodak random access carousel slide projector and a microprocessor (Faulkner, 1982). Later, a project using interactive video to teach communicatively disabled retarded citizens to use Bliss symbols (a graphic symbol language) was developed and used in Mississippi (Payne & Antonov, 1982; Payne & Tew, 1984).

An ongoing project to develop and demonstrate the utility of interactive video for teaching community adjustment skills to mentally handicapped adolescents is underway at the University of Oregon Rehabilitation Research and Training Center in Mental Retardation. The interactive video unit is one of the first curriculum products developed by the federally funded project. An example of the work being pursued in this project is reported by Carter, Browning, Nave, and White (1985). The purpose of this project is to determine whether or not learning performance varies as a function of the nature of feedback in error correction, and whether or not mentally handicapped adolescents could acquire knowledge through the computer assisted interactive video unit. Twenty-six subjects were matched in pairs based on pretest score and age, and then randomly assigned to two treatments. Group mean IQs were 58 and 60. Group A received extended informational feedback and Group B received a briefer form of informational feedback. Both groups received information via the interactive video unit. Results indicate that significant learning occurred for both groups leading to the conclusion that interactive video is effective as an instructional medium with mentally handicapped adolescents, however, there was no difference between the groups on the types of informational feedback used (extended versus brief).

Interactive video curricula have been developed at a number of different sites. One example is the extensive work of the Interactive Video for Special Education Technology (IVSET) project at Utah State University. Programs in six curriculum areas for handicapped learners at the primary age level were field tested with very favorable results (Thorkildsen & Hofmeister, 1984; Friedman & Hofmeister, 1984). Currently their efforts center on developing curricula to teach social skills to retarded adolescents.

The reports on utilizing interactive video in instructional settings indicate several advantages of the interactive video approach over computer assisted instruction. Primary among these advantages are the life-like quality of the pictures which can be used in contrast to computer generated cartoons, the speed with which frame selection is achieved, and the high motivating effect of the technology with this population.

SUMMARY: WHAT WE HAVE LEARNED FROM THE RESEARCH

What we have learned from existing field research with this population of learners is (a) that microcomputers enhance the quality of life and the quality of education for certain handicapped and/or disadvantaged pupils; (b) that microcomputers mediate the interaction between teacher and pupils by providing consistent and patient presentations of information; and (c) that microcomputers maximize services to the handicapped and/or disadvantaged by more rapidly processing the mundane and time-consuming tasks that accompany teaching and learning.

This review may be used to foster new research and demonstration projects utilizing microcomputer technology for handicapped and disadvantaged learners because it has identified a variety of issues to be addressed. Early accomplishments, especially in assistive communication and environmental control devices, must be augmented by greater miniaturization of the often bulky apparatus. The emerging thrust to embrace computer technology throughout education, and technology's potential for reshaping special education, requires that a sound research base be developed.

In those areas in which empirical study is prohibitive, systematic inquiry can provide a rich source of information on implementing computer based education. Synthesizing such systematic inquiry may result in a table of specifications or profile of effective computer applications with certain populations and then be used as a basis for empirical study.

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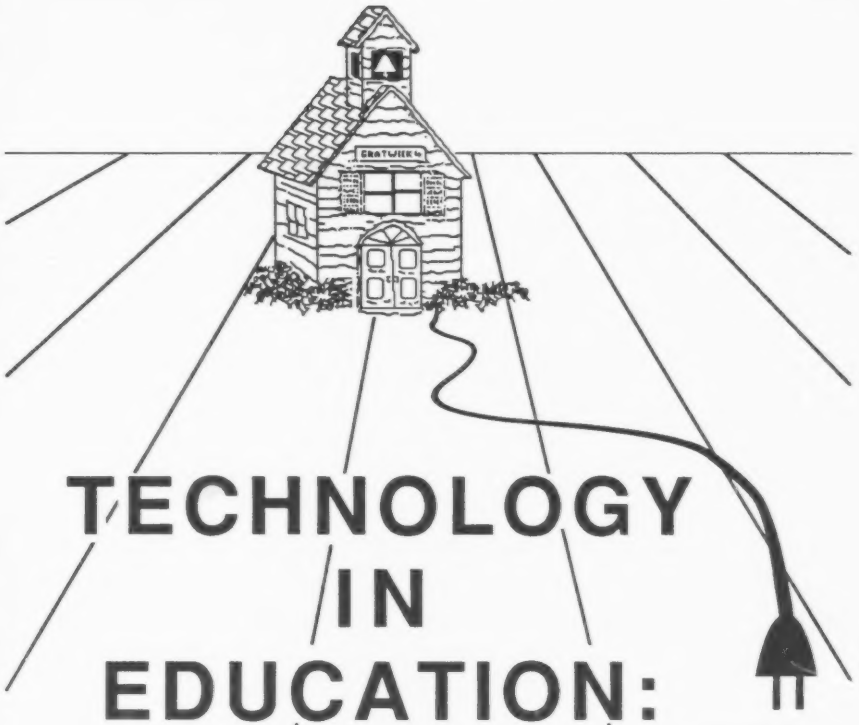

TECHNOLOGY IN EDUCATION:

APPLICATIONS

A SYSTEMS APPROACH FOR THE DEVELOPMENT OF COMPUTER-BASED INSTRUCTION IN PRIMARY GRADES HEART HEALTH CURRICULUM

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Ideal instructional development processes are most often described in a model format based on the attributes of the selected media and methodology to present prescribed instructional events. Most models are based on the premise that the design should determine the media and methods. For this study, a search of the literature was undertaken to identify models of instructional software development. The search was necessitated by the receipt of a grant from the American Heart Association, Texas Affiliate, to develop a curriculum for elementary learners. The complete project of five heart health curriculum modules for grades one, two, and three was to be based on an experiential approach to learning which would include traditional and computer-based curricula.

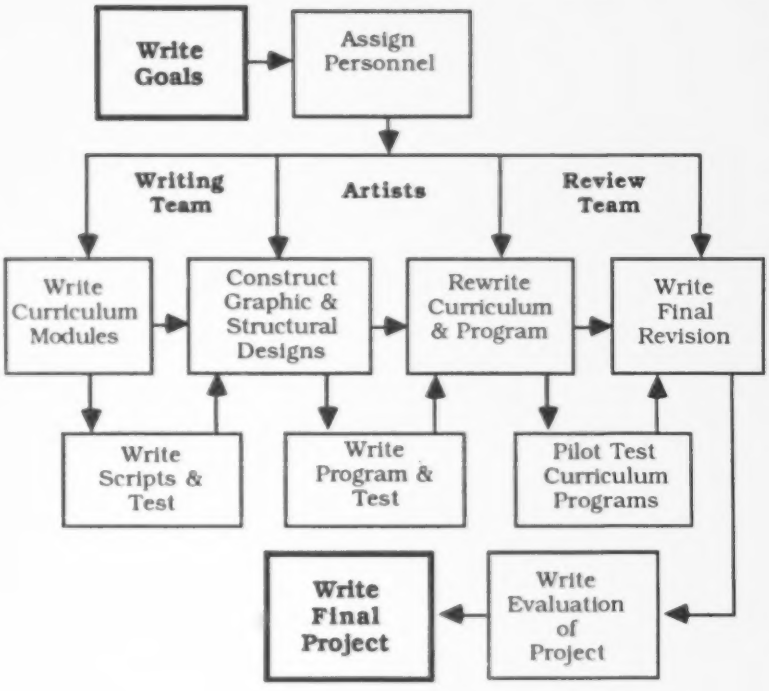
A study of the literature produced a logical selection which demonstrated a systematic approach to curriculum development. The Irvine Model, the production system adopted for the current project, was developed by Alfred Bork and associates at the University of California at Irvine (Bork, 1981). It has been used to produce a sizable amount of computer-based learning materials ranging from elementary school through the university level. Bork defines twelve stages or phases of the system,which are fundamental to all production systems for educational materials (Bork, 1984). These twelve stages are:

1. Preplanning
2. Production management
3. Objectives and specifications
4. Training activities
5. Pedagogical design
6. Visual design
7. Technical development
8. Editing
9. Evaluation
10. Revision
11. Marketing
12. Distribution

The Irvine Model described by these twelve stages was followed in the management of the curriculum project for the American Heart Association and served as the model for the development of microcomputer software for the third grade curriculum. A layout of the development process is shown in Figure 1. As this layout indicates, the software development sub-project was partially initiated through the curriculum writing team and partially through a computer-assisted Instructional Task Force which served as an outside review team for the microcomputer software.

A brief description of each of the components of the Irvine Model for software development is presented in this paper with a description of how the procedures were followed in the development of this curriculum project. Specific emphasis is directed to the procedures followed in the software development phases of the project.

Figure 1. Modified Irvine Model for Development of Heart Health Curriculum and Software



Procedures and Discussion

Preplanning Activities

The preplanning activities involved the writing of a proposal to the American Heart Association, Texas Affiliate (AHA). During the funding phase of the proposal the principal investigators of the project negotiated with that organization to clearly define the goals of the project. The goals and concepts of the intended curriculum project had been set a priori by a task force of health and education professionals for the American Heart Association. These goals and concepts described the intent of the curriculum and software to be developed.

Production management

Production management was entrusted to two professors at Texas A&M University who served as the principal investigators for the project. The management procedures followed were a Structured Analysis and Design Technique, commonly referred to as SADT (Kurtz & Bork, 1981). This technique is a way of describing the project activities and a mechanism for

managing the sub-projects. The SADT also provided the opportunity to identify the status of each part of the project at any given time.

Objectives and Specifications

The objectives and specifications of the proposed curriculum and the software were developed in two preliminary meetings. A group of classroom teachers, health education specialists, and medical specialists were called together to establish the objectives and specifications for the instructional modules in heart health for the three primary grades. These specifications and objectives were then reported to a task force for computer-assisted instruction for their consideration in terms of software recommendations. Both groups produced software ideas in brainstorming sessions which provided the basis for software objectives and specifications which were directly related to the curriculum concepts.

Training Activities

The group of classroom teachers, health education specialists, and medical specialists met for four 3-hour work sessions. Training for this part of the team was given in the first of the four sessions. During the first session two investigators explained the timeline and the production management design; the goals and concepts for the curriculum project of the American Heart Association were defined. The remaining team sessions were spent writing specific objectives and brainstorming learning activities to reach these objectives. It was determined that the topics to be included, based on the goals of the American Heart Association, would include: (a) structure and function of the heart; (b) activity and rest; (c) nutrition; (d) blood pressure and pulse; and (e) smoking avoidance.

A second type of training was provided for the artists and programmers. These individuals needed to understand both the objectives of the software and the developmental level of the targeted user. One 3-hour session for programmers and artists was provided by the author. Graduate student artists and programmers were hired because of the availability of very capable individuals.

Pedagogical Design

The pedagogical design stage of this project was the phase in which the instructional materials were fully specified. This was perhaps the most critical stage in the entire production process because it provided the overall shape and substance of the product which was developed. It was determined that there would be five modules of instruction for each grade, with computer-assisted lessons being a part of each module in grade three.

An outside review team was selected by the American Heart Association to review the written materials which were prepared by the writing team and the principal investigators. The review team, comprised of curriculum experts in a large Texas school district, provided quality control in terms of appropriateness of materials and helped to avoid common pitfalls in writing curriculum materials.

A coordinated effort was made to utilize the writing team and review team to the utmost for the pedagogical design. The writing group worked together for four 3-hour sessions in the creating stage, and the review team worked with the principal investigators on three occasions, for 4 hours each, to

formatively evaluate the materials for proposed teacher usage, student capabilities, and pedagogical specifications for learning.

The microcomputer software for the five modules at grade three was based on the exacting nature of the tasks outlined or described through these two teams working with the investigators. Flowcharts were designed to show program structure and general procedural formats of the microcomputer programs. Sketches of specific screens were drawn to show how the material was to be displayed, and text was written to explain the procedures of branching to be followed in the program logic. No fixed templated logic structures were utilized so as to avoid limitations on the software. Writers were encouraged to make instructional choices entirely on pedagogical principles and to feel free to make creative choices for instruction.

Visual Design

Sketches of specific screens were drawn to show how the material was to be displayed, and text was written to explain the procedures of branching to be followed in the program logic. From these sketches, more exact screen designs were created with precise procedural information shown on each page to guide the programmer. Ideally, the person responsible for doing the visual design should be one skilled in the use of on-line graphics, graphic design for brochures, or magazine layout. However, securing a person with these skills was not possible in the development of these software modules due to limitations in project funding. The layout work was prepared by the author for the software visual design and program procedural design.

Technical Development

This stage of development included the coding of the computer-based learning activities by the graduate student programmers hired especially for this project. The procurement of capable programmers of educational software is another process worthy of discussion. When trained programmers are not available from the start, it is advisable to screen those who are willing to work in this capacity. Attributes of programmers include: (a) a high degree of creativity, (b) above average intelligence, and (c) the ability to solve problems. Decisions related to selection of the computer system, what disk operating system, graphics package, and editing program to be utilized were components of this stage. The Apple II microcomputer with at least 64K of memory was selected because of its availability for instructional purposes in Texas schools. Programmers were asked to keep an extensive list of CALL numbers, PEEKs, and POKEs for those specific functions on the Apple IIe which provided an efficient way of programming and assisted in the speed of performing necessary graphic functions.

Editing

Editing of the complete heart health curriculum package, including the computer software, was accomplished in several stages. The first stage of editing occurred during the pedagogical design phase when the instructional ideas were written for formal presentation and review. The second opportunity for editing occurred when the review team of curriculum experts read and commented on the content and pedagogical procedures. Software editing occurred initially after the complete written and visual layout was constructed. The second software editing took place after the first copy of each program was completed on disk. When the five pieces of software were

complete, they were sent to specialists in educational software, heart health specialists, and elementary classroom teachers for review. Each of these individuals was asked to search the program for visual and content errors. Each of the five instructional programs was submitted to the American Heart Association Computer-assisted Instructional Task Force for editorial comments. Subsequently, the software was revised based on the pilot testing in three elementary schools.

Evaluation

Software evaluation was based on the congruence of instructional strategies and content sequence with pedagogical principles. Five Texas school districts were selected for pilot testing the curriculum and computer software. Selection of these school districts was based on similarity of student populations and feasibility of travel for the author in working with the teachers during the pilot testing period. Proposals for pilot testing the curriculum packages, including the five computer programs, were accepted in 3 of the 5 school districts solicited. The evaluation design for grade 3 in all three districts included: (a) a control class which would not receive instruction; (b) an experimental class which would receive curriculum materials without the instructional software; (c) an experimental class which would receive curriculum materials with the instructional software; and (d) an experimental class which would receive instruction only through the microcomputer software package. Each of the four groups was pre-tested and post-tested over heart health information contained in the curriculum modules and instructional software programs. The experimental teachers were trained in a workshop to prepare them to teach the heart health modules and to show them how to use the software for instruction. The statistical treatment of the data was conducted to provide information for the revision of the curriculum and software products.

Other methods of evaluating the software included a Likert-type scale to measure teachers' opinions regarding both the instructional modules and the software component. Each student completed a Thurston-type (agree or disagree) questionnaire to measure his/her opinions about the class activities and the computer software. Additionally, teachers were asked to make constructive comments on each activity of the modules.

Revision

Results from the curriculum and software evaluation indicated that changes were needed. Specifically, editorial and format changes were made in the curriculum guide for teachers, a slide-tape presentation was revised, some class activities were omitted to permit the modules to fit into a 5-day instructional plan, minor content and procedural changes were made in three of the software programs, and the software documentation was revised to include more activities and procedural descriptions. Two of the software programs were not selected to be used in the final curriculum package based upon the evaluation of student knowledge gain and from comments rendered by experts in heart health information. Programs not selected dealt with the topics of nutrition and blood pressure; the programs retained for use with the heart health modules dealt with activity and rest, structure and function of the heart, and smoking avoidance.

Marketing

Although a component of the Irvine Model, marketing was not a phase of the development of the curriculum. The American Heart Association, Texas Affiliate accepted the responsibility for marketing the curriculum package after it had been pilot tested. A field testing of the curriculum was planned as a second level of evaluation by the American Heart Association prior to the marketing phase. Bork (1981) suggests that evaluation, revision, marketing, and distribution may be considered together. He also suggests that very little marketing experience is available for computer-based learning material. Marketing generally must be in the hands of specialists who are experienced in this area. Educators and researchers often are not skilled enough to prepare and implement a successful marketing plan.

Distribution

The network of regional offices of the American Heart Association provides one avenue for distribution of any of that organization's instructional products. The distribution of the the curriculum and software was not included in the production process of this work, since it is carried out through the organizational structure of the American Heart Association.

Conclusions and Recommendations

The systems approach followed in this project provided structural support to the principal investigators. This model provided direction in the planning stages and yielded information on how to structure the teams for writing and reviewing the products. In reviewing this completed project, the following suggestions for computer-based software development are given.

1. Depend on a team of specialists to develop, monitor progress, and guide production of the software from beginning to end.
2. Select an outside review team to monitor progress and productivity.
3. Select bright, creative, computer encoders who have an interest in the instructional topic of concern.
4. Provide enough time during stages dealing with objectives and specifications, training activities, and pedagogical design so that the products do not suffer from weak objectives, concepts, and inappropriate pedagogical design.
5. Employ an expert in visual design if possible. If not, study the product during the visual design phase carefully in storyboard format to determine how every feature of the program should function and what features of the computer system should be used to direct learning.
6. Structure the evaluation components so that questionnaires and other instruments for teachers and students are specific enough to measure the worth of each component of the curriculum.

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MONITORING STUDENT PROGRESS WITH MICROCOMPUTERS

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The incentive to infuse computer technology into the schools and classrooms of Texas was recently encouraged by State reform legislation in the area of broad curricular changes as well as in specific calls for computer literacy training of public school students. Accompanying the specific mandates for training students in computer skills came an implied necessity for the acquisition of resources and the inculcation of the skill domain for professional teacher personnel. In the previously mentioned area of general curriculum change, the legislation identified certain "essential elements" representing basic minimum learnings in the various content domains to be mastered by students. These essential elements were to be reflected in teacher lesson planning and presentation; they implied measurement of mastery of the learnings. The following study brought together three important areas: computer technology infusion, monitoring/measuring of essential element mastery, and teacher skill training in the use of the technology. With the profound impact of computers upon the lifestyles of modern society, it becomes mandatory that students in our schools and the professionals who operate the school systems become fully involved with the technology.

PURPOSE

The project centered on the development of a software package for teachers to track student acquisition of the essential elements in specific course matter by the use of microcomputer technology. Software was developed which permitted the utilization of a content mastery test correlated to the essential elements and administered by way of direct interaction between the student and the computer. The software also analyzed mastery analysis and reported results on an individual and a group basis for the teacher and/or administrator's immediate use.

BACKGROUND

Computer technology, has had direct and indirect effects upon our homes, our workplaces, and our schools. The ability to handle vast amounts of information, to engage in problem solving, to communicate with new tools and with new formats, to think, to create, and to play are very much a part of the promise and potential of today's computers (Office of Technology Assessment, cited in Roberts, 1983). Computers have made inroads into the office, the production line, and the home, but their use in the field of education has been limited until recently. The picture has changed radically in the last few years, and now educators are involved with a multitude of projects and endeavors which are attempting to appropriately merge technology with the teaching-learning process. In 1983 it was estimated

that there were close to a quarter of a million microcomputers in elementary and secondary schools (Roberts, 1983).

Educators as well as the general public perceive that there is a considerable potential for the application of computers in the classroom. However, like the technologies before it, the computer has not yet substantially changed the way children are taught or how classrooms are managed (Norton, 1983). If this powerful medium is not used to its fullest capacity and if it is not allowed to take its rightful place in the educational setting, educators are doing an injustice to the students and the personnel involved in the day to day tasks of educating the nation's children.

Computer technology can play an important part in changing the instructional climate in a classroom and giving the teacher freedom to plan and implement programs that were impossible before the advent of computers. Student strengths and weaknesses can be diagnosed at a level of accuracy that has not been achieved in the past, and programs can be planned to meet individual needs. Many routine functions of the classroom, such as averaging grades or making printouts of lesson plans can be completed with a microcomputer. Schools across the state of Texas are using microcomputer technology to track and monitor the essential elements of Chapter 75 of the Texas Administrative Code (68th Texas Legislature). Elaborate systems have been developed in some school systems that generate reports concerning individual student progress in the mandated curriculum. Through the efforts of regional educational service centers, computer terminals have been installed in many schools, and efforts have been made to write the behavioral objectives and the criterion-referenced tests necessary to develop the software programs needed for mandated report generation. Regional service centers also have been helpful in training school district personnel in the use of hardware and software and in program management through the provision of maintenance contracts and technical assistance. Commercial software producers and individual program developers have recently been creating microcomputer software programs that facilitate tracking and monitoring of individual student progress in the essential elements. Computers can aid the school administrator in managing time, resources, and personnel to achieve the central goal of providing the best educational setting to foster and promote educational opportunity for young people (Bratlien, 1985).

THE STUDY

This study, conducted in the Bridge City Independent School District (1985), had as its primary emphasis the development of an instructional management system which provides teachers and administrators current information on the progress of individual students in relation to the essential elements of Chapter 75. The project was designed to aid personnel in the elementary schools of that district in implementing Chapter 75 and House Bill 72 educational reforms (68th Texas Legislature in Special Session). Three objectives of the study were to develop an information management system whereby individual student mastery of the essential elements of Chapter 75 could be monitored, to develop a procedure for using microcomputers for implementing the information management system, and to help the elementary teachers of the district become more skilled with microcomputers through the use of the information management system developed.

The school district purchased the necessary hardware to establish microcomputer laboratories in each elementary school of the district. Since

both elementary schools had computer laboratories, a corollary purpose of the study was to design an activity which would maximize use of the microcomputer laboratories. From a needs assessment it was determined that software was needed which not only would generate reports on individual student progress, but also would allow students to use the microcomputers as test-taking instruments. In framing the parameters for the study, research questions were formulated which considered the development of an appropriate information management system for the school district which would permit the monitoring of essential elements mastered in coursework and which could be utilized via microcomputer. Specific aspects of questions posed involved the determination of a method to test for mastery of essential elements as well as the development of an appropriate computerized procedure for administering content mastery tests and reporting results.

THE PRODUCT OF THE PROJECT

Data gathered from the literature, investigations of computerized management systems, interviews, and questionnaires were used to establish criteria for an effective management system. These criteria included:

(1) The system should rapidly identify specific student errors.
(2) The system should provide the teacher with data about individual student progress in the student's acquisition of skills.
(3) Reports and printouts should be easily accessed and interpreted.
(4) The system should free teachers from burdensome paperwork and should be accessible to them.
(5) Turnaround time between testing and obtaining data for instructional planning should be minimized.
(6) The system should not be so detailed that it becomes impractical to implement.

The educational product that was developed to respond to these criteria consisted of a microcomputer software program entitled Mathematics Objective Test, Level 5 (MOT). Research indicated that the software program should also include the following characteristics: the program should be menu driven and user friendly; student and class information should be easily accessible; students should not be able to gain access to other student or test information; the program should allow editing of test questions and objectives; and it should be expandable to allow for additional student information. Finally, the criterion-referenced test should be on the software program with the capability of generating copies of the test as well as the objectives measured.

As stated previously, the MOT was developed to permit students to complete criterion-referenced tests on a microcomputer in the computer laboratory. The test was designed to measure student achievement of behavioral objectives in fifth grade mathematics which were correlated to the essential elements. One six-weeks period of instruction was covered since criteria established for the information management system had stated that the system should not alienate teachers or students by covering a long evaluation period. A six-weeks period was considered to be of optimal length for testing while still being flexible enough to fit the teacher's instructional schedule.

The software program was designed so that each student taking the test on the computer had a diskette of the math test. The MOT program was

divided into two sections - a student test and a teacher management program. The teacher management program could be accessed only through the use of a password; therefore, a student could not access that section of the software program for the purpose of viewing other student scores or gaining access to test question answers. After accessing and completing the test, a student asked for the teacher data disk, which had been formatted using the utility functions file of the software. At this point the MOT disk was taken from the computer and the teacher data disk was inserted, permitting student answers to be recorded for access later by the teacher. Whenever the classroom teacher was ready to gather and consolidate student information from the data disk, a computer with a double disk drive was used. At this point the teacher had the option of making a hardcopy of the data. Data were obtained through three programs resident in the teacher management file which were reached through the Test Scores Information section. The three programs provided the number and identity of students in a class who had mastered a particular objective, as well as the objectives which had not been mastered, in order to initiate remedial action if desired. School administrators were able to use the teacher information to gather the necessary data for campus and/or district reporting.

The teacher management menu of the software additionally contained a utility functions file that housed the Edit File Disk Information program. This program allowed the teacher to change test questions, change the teacher's name and the student's name and identification number on a data disk, transfer a student's file to another data disk, or delete a file. The utility functions also permitted the viewing or changing of a password, the formatting of a disk for use, and a cataloging of the data disk. A hard copy of the test and the objectives measured by it, could be generated through the teacher management menu.

Several teachers in the study were computer literate and had no problem understanding the mechanics of the MOT; however, each was shown the correct manner in which to utilize the software program and how to generate necessary information. This orientation was conducted during the time their class was in the computer laboratory for its regular computer lesson. In learning to use the MOT to obtain student information concerning the mastery of mathematics objectives, teachers who had not previously been acquainted with the use of microcomputers had an opportunity to gain a degree of computer literacy. Minimally, they were successful in learning to use a software program and to see how that program held potential rewards in student measurement and recordkeeping.

FIELD TESTING

After the product was developed, preliminary field testing was conducted at one of the district's elementary schools. Questionnaires were developed for the students, the classroom teachers, and the computer laboratory aide. Information from those instruments and from interviews with the teachers and school administrators provided valuable insights on improving the system. The instructions on the student test were revised to respond to a computer key so that the instructions could be removed from the screen at the student's command rather than remaining for fifteen seconds. This feature accommodated students who read and understood the instructions more quickly and permitted them to go on to the subsequent sections of the test at their own pace. Teachers' management files were revised to a two-drive system exclusively, this affording greater ease of operation for teachers and an added measure of security. Printout revisions were made to

accommodate a more functional and pleasing visual appearance to hardcopy output.

One major revision consisted of adding another program to the Individual Student Information section of the software to permit a printout of the entire class with two sets of individual student information per page. Another significant revision entailed the addition of a fourth question to the student test. The original version had consisted of three questions to measure each objective. Correctly answering two of the three questions gave the student only a sixty-seven percent level of mastery, whereas the State minimum passing requirement was seventy percent. By adding a fourth question, the student could obtain a seventy-five percent level of mastery when three of the four questions were answered correctly.

Main field testing took place at Hatton Elementary School where the mathematics test in a paper-pencil format was given to approximately one half of the fifth grade students while the other half of the students took the computerized test in the computer laboratory. Again, questionnaires were administered to the students, the classroom teachers, and the computer laboratory aide. Using the information from those instruments and from interviews with the teachers and administrators of the school, minor adjustments were made in the software program. One such adjustment consisted of a change in the printout of the individual student information. Too much space was taken between the two student profiles on hardcopy printout, and the last page of the report was not formatted properly to leave non-printed allowances between page perforations. Additional recommendations were made concerning further revision that would allow optimal us of the product in the school district.

RESULTS

Data collected from questionnaires revealed that the students considered the computerized test easy to use, the instructions were easily followed, and the test questions were not confusing. Students indicated the computerized test was not boring and the testing situation was well organized. Overall, students had a favorable attitude toward taking the test on a computer. There was a slight tendency for the higher ability level students to have a more favorable attitude toward the computerized test than those with lower abilities. The findings from the data indicated that the students were not intimidated by the MOT and would rather take a test in that format than take one using paper-pencil format in the classroom.

Teachers indicated that the test successfully measured the fifth grade mathematics objectives and that the information gained from it was easily obtained, easy to read, and easy to understand. They also stated that the information gained from the MOT would be very useful in planning mathematics instruction, although there was a need for other information. The teachers stated that they felt it would not be feasible to test all of the fifth grade mathematics objectives using the MOT format since only a small number of their students could take the test at one time.

The computer laboratory aides indicated by their responses that the software program was easily administered and did lend itself to a favorable testing situation. They stated that the children had little difficulty in handling the software and the teachers had few problems getting the necessary information from the program. The aides disagreed with the teachers in that they felt it would be possible to test all of the fifth grade mathematics objectives in a similar manner. They stated also that testing

all of the fifth grade students during their computer lab time would be feasible.

CONCLUSIONS

The data collected during the study indicated that in order to implement the information management system as described, a school district should have curriculum guides that correlate the district's curriculum to the essential elements which are outlined in Chapter 75 of the Texas Administrative Code. Teachers need to be trained in the use of the curriculum guides and in the use of alternative methods of delivering instruction in a way that their time in the classroom would be better managed during the reteach and retest cycle. Criterion-referenced tests should be written to measure the objectives as outlined in the curriculum guides for a six-week period of instruction. Teachers and building administrators should be trained to use the software program so that both would have access to the necessary student information.

With the implementation of Chapter 75 and House Bill 72, management of information is vital. The efficient management of information will free the principal and other administrators and teachers to focus their time and energy on the instructional program. Microcomputers can facilitate a management system which will make this goal more attainable. Utilization of microcomputers as free-standing, independent technology has a unique potential to make significant contributions not only to learning itself, but as efficient managers, fostering the saving of time and work for teachers and administrators.

Although the information management program that was developed as a result of this study is unique to one school system, it can be used as a model from which others can be patterned.

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COMPUTER-BASED TESTING WITH YOUNG CHILDREN

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This paper presents an overview of computer-based testing (CBT). Of particular interest in this discussion are the various techniques of CBT, as well as some indication of its relative usefulness as a method of testing the intellectual skills of young populations. In addition, a study involving computer-based testing of analogical reasoning in kindergartners and second graders will be briefly described.

Computer-Based Testing with Young Children

Testing has become a way of life in American education. Almost from the moment children step foot inside a school building, they are bombarded with formal tests designed to assess their readiness for learning, their achievement, their aptitude, or their motivation. A major concern in schooling is the assessment of cognitive processes. In some cases the testing of cognitive skills and abilities is initiated even before children enter kindergarten. In an attempt to make psychological and educational assessments more reliable and more informative, computer technology is being investigated as an efficient means for test administration. In this paper, we will consider briefly how computers are being used in schools today, examine computer-based testing, and discuss a study of computer-based assessment of analogical reasoning with young children.

Computer Use in Elementary Schools

The use of computers in U.S. public and private schools is growing rapidly. As of January 1983, about 42% of elementary schools and 68% of junior high schools had at least one instructionally-dedicated microcomputer (School Uses of Microcomputers, 1983). However, computer application in the elementary schools still remains remarkably limited in scope. Many school systems still have not incorporated computer education into the mainstream curriculum. There are some notable exceptions where State Legislators (e.g., Texas) have acted (for better or worse) and mandated computer education (whatever that may be). A central question is how, or if, computers are being used in the classroom as a testing medium? Computers are becoming more and more frequently utilized as a testing medium at the college level (Kapes, Borman, Garcia, Compton, & Kimberly, 1985; Wood & Ortega, 1981). But how are computers being used in primary and preschool classrooms?

Due to the relative newness of computers to primary and preschool classrooms, virtually all the research investigating computer use is general in its scope, and therefore not directed toward computer-based testing. Some highly motivated teachers (typically in secondary schools, teaching math, science, and/or computer science) may use their class microcomputer as an aid in constructing teacher-made tests. However, there has been little, if any, investigation in using the computer as the testing medium. Education is just beginning to incorporate computers into the classroom and educational researchers have not yet begun to transfer the major educational and psychological tests to computer form.

Only in about the last five years has the utility and flexibility of computer technology been extended downward into the primary and preschool classrooms. In the preschool and early childhood classrooms, the computer is often viewed as a novelty, and used as a reward mechanism. Much of the current research is focused on how these young children view and interact with the computer.

Taylor (1983) investigated the integration of computer science into an existing campus child care center for children aged 2.5 to 5 years. Her results indicated that these young students not only learned the basic functional units of a microcomputer system and its operation but the children viewed the microcomputer as a reinforcing tool. Her results also indicated that working with the computer did not lead to social isolation. In a related study, Nieboer (1983) investigated the effect of introducing a microcomputer into a preschool classroom. The results indicated that while the computer did not dominate a child's play behavior or disrupt the flow of classroom activities, the computer provided additional opportunities for fine motor development (manipulation of a joystick), creative involvement, verbal expression, problem solving, success, and pride in achievement.

Nida, Lipinski, Shade, and Watson (1984) looked into the effect of microcomputers on children's social behavior in preschool classrooms. Citing evidence from two studies, these authors concluded that the presence of a microcomputer in the classroom does not diminish the children's social behavior. Similar conclusions were drawn by Swigger and Swigger (1984). Swigger and Swigger found that the introduction of a computer into the environment did not disrupt pre-existing social patterns. Margot and Armstrong (1983) have suggested that early exposure to computer in a preschool environment can build self esteem and a sense of control as well as provide early academic lessons such as logic, pre-mathematics, pre-reading, and problem- solving.

In one study of preschool children's behavior with a microcomputer, Klinzing (1985) found a sex difference in the relative amounts of time four-year olds spent using a microcomputer. Klinzing found that boys spent more time using the microcomputer than did girls but these results did not extend into the five-year olds. In another study investigating the effects of gender on computer programming ability in three and four-year olds, Sprigle and Schaefer (1984) failed to find a significant effect for gender. Moreover, these researchers did demonstrate a significant effect for age similar to Klinzing's findings.

In summary, the research on the impact and use of computers in early childhood classrooms has primarily focused on how young children accept and freely use the computer. Evidence suggests that computers can be a powerful motivating force for these young children. Moreover, computers are accepted and integrated into existing social systems without strong support for a gender effect. As the availability and novelty of the computer begins to

wear-off, more traditional educational uses of the computer will begin to be explored such as CAI and testing.

Much of the research in the primary grades is focused more on using the computer as an aid in classroom activities and curriculum enhancement. One of the most influential researchers in this area is Papert (1980), the principal author of the programming language LOGO. LOGO is often used to teach a variety of mathematical and problem-solving skills to primary-aged students (Aleta, 1985; Hillel, 1985; Oldfield & Oldfield, 1985). Microcomputers are also used in special education classes (Frank, Wacker, Berg, and McMahon, 1985; Lehrer, Harckman, & Archer, 1985). However, the most common use of computers in elementary school classrooms is for presenting supplemental CAI to the curriculum. Virtually all mainstream courses have a wide variety of software available to teachers. CAI can be broken down into six categories: (a) drill and practice, (b) tutorial, (c) demonstration, (d) simulation, (e) problem-solving, and (f) educational games. In the early grades (K-3) much of the CAI is drill and practice, tutorial, or demonstration. Not until the later grades (4 and beyond) is there greater availability of the more advanced CAI.

Using the computer for administering tests both in preschool and in primary school currently is not practical for several important reasons. First, a large number of computers is required for classroom testing. Most schools do not have the facilities to support such an expense or the administration decides to distribute the available computers in many classrooms. A second major reason for the lack of computer-based testing in the schools is that major educational tests administered in schools are not yet available in computerized form. Moreover, most teacher-made tests are not administered on the computer because of several reasons such as teacher know how, computer availability, and limited testing time. In short, computers offer a new and exciting method for presenting testing materials over traditional paper and pencil methods but our educational system has not yet begun to explore the possibilities of this new testing medium.

Computer Based Testing

Computer Adaptive Testing

In general, there are three categories of Computer Adaptive Testing. In this first major category, computer technology is used only for processing the test and test results. Specifically, the computer is used for item storage called item banking and for scoring test results. By using the bank of test items stored in the computer, the examiner can readily generate alternative forms of tests complete with scoring key. For example, a third grade teacher is working on multiplication tables and wishes to have available a number of tests for use in screening, evaluating, or reinforcing students' understanding of specific timetables. The teacher would store a number of problems into the computer to be sampled when needed.

In the second class of CAT, the computer's power is used more creatively. In addition to item banking and test analysis, the computer plays an important role in test construction. Computers are programmed with an algorithm that allows the computer to generate individual test items. For example, a primary school teacher wishes to make up an achievement test for the end of an instructional unit on the addition or real numbers. A computer could be programmed with an algorithm such as A + B = C where A, B, and C are real numbers randomly generated by the computer. The computer would

not only generate the test, it would generate individual test forms for each student along with a scoring key.

In the third category of CAT, the computer is utilized as the testing medium. This type of CAT not only has data processing benefits and the potential for item generation based upon algorithms, but it also possesses several other options and alternatives to traditional paper and pencil testing. Different but equivalent tests can be administered to each student. Test items need to be typed into the computer once, or not at all, if the subject domain can be sampled by item algorithms as in mathematics, chemistry, or physics. Test scoring can take place immediately following subject's response, thus enabling instant feedback to the student. Response time measurements can be recorded thereby adding important information beyond simply a total test score. Color, sound, and animation can be added to a test to make it more true-to-life, or complex relationship can be simulated via computer but not be paper and pencil tests. Finally, one of the major advantages of this type of CAT over traditional paper and pencil instruments or the other two types of CAT described above lies in its ability to focus rapidly on areas of student difficulty and thereby pinpoint learning problems (Hunt & Pellegrino, 1984; Okey, 1982).

The ability of CAT to identify learning problems directly and quickly originates from the computer's ability to score test items immediately following presentation and response. For example, prior to administering the first test item, CAT will make a best guess at the student's ability level, or it may directly ask the student what his/her ability is. Based upon this information, CAT will select an item from the item bank or generate one based upon a preprogrammed algorithm. Following item presentation on the CRT and subsequent answer by the student, CAT will make a new estimate of the student's ability level before administering the next item. The updated estimate of the student's ability level is used in the selection or generation of the next item.

CAT typically uses item response theory (IRT) for making the estimates of the student's ability level. Items are selected by CAT based upon either one, two, or three parameter IRT models. All item statistics are stored along with the individual items. Thus, CAT can efficiently tailor a test to assess a student's knowledge over a given topic in the most efficient manner by presenting only those items that best discriminate the student's ability.

Measurement Issues in Computer Adaptive Testing

As noted, computerized testing is becoming a predominant means of psychoeducational assessment. There is concern, however, that the introduction of computers into the testing environment could change both the nature of testing and the interpretation of test scores (Matarasso, 1983). Two important issues need to be explored and understood as psychologists and educators turn to the computer as the testing medium. One issue focuses on the advantages and disadvantages of testing a person with a computer regardless of the test's content. The second issue is concerned with whether or not the content of mental tests can be or should be changed in computerized testing (Hunt & Pellegrino, 1984).

Before getting involved in the relative advantages and disadvantages of computer-based testing, it may helpful to understand a little about traditional mental tests. Tests of mental ability are typically classified as either group- or individually-administered tests. The Otis-Lennon Mental Abilities Test (Otis & Lennon, 1967) is an example of a group-administered mental test, while the K-ABC (Kaufman & Kaufman, 1983) is an example of a test that is

individually administered. Group tests are commonly paper and pencil tests. The fixed format characteristic of group tests generally results in a more cost effective test when large bodies of people need to be evaluated.

Individually-administered tests, on the other hand, while more costly to give, are more valid than the group administered test for two reasons. First, the examiner could serve a stimulus presentation function, thus ensuring the examinee is presented with the appropriate item. Second, the examiner could serve a control function by ensuring that the examinee understands the directions and is motivated to do his/her best. Third, examiners are often required to use complex branching algorithms to test examinees which are based on both examinee's responses and general behavior. These branches are often highly inferential and require a great deal of expertise. A fourth difference between individual and group tests is that individually-administered tests may have physical objects to manipulate, almost never true of group tests.

Test Administration

Computer-based mental testing falls somewhere between the group- and individually-administered test. It appears that computer-based test borrow several of the advantages of both group (paper and pencil) test and individually administered tests. First, almost any question that can be presented in a paper and pencil format can be also presented on a CRT using a computer. Second, the computer can be programmed to act like the examiner to ensure a controlled testing environment, termed an expert system. Third, test scoring and administration can be performed by the computer as described in the previous section. Some of the additional benefits of a computer-based test lie in easier alteration of test items, collection of test item and examinee related statistics, and in test development. Interactive testing, can, therefore, take greater advantage of a given amount of testing time thus providing a potentially better assessment of a subject's true ability level.

Trait measurement

The second major issue revolving around computer-based testing is whether or not the testing materials (i.e., computer and supporting software) might change the psychological trait being assessed. This issue can take two forms: The psychological trait could change equally for all people, or computer-based testing could selectively change the trait in some people but not in others. For example, a manipulative task such as stringing beads in a specified sequence might be simulated using a graphical program on a computer. Is the ability changed by requiring the examinee to represent the task two-dimensionally and to manipulate a computer apparatus (such as a joystick) instead of the beads? There is no clear answer to this question yet (Hunt & Pellegrino, 1984).

In one study Lansman, Donaldson, Hunt, and Yantis (1982) demonstrated that there are separate factors for test item presentation mode but that they do not interact with test form. This finding suggests that there are specialized abilities needed for different test modes, but that either test mode is valid, providing that the relative factor loading does not change across testing conditions. There is additional support for the contention that computerized and paper-pencil tests are essentially equivalent in two studies with a computerized and paper-pencil form of the Ravens Progressive

Matrices Test. In both studies, the computerized and paper-pencil forms resulted in equivalent results (Calvert & Waterfall, 1982; Rock & Nolen, 1982).

Affect

Level of motivation may be an important factor in determining whether or not a computerized test favors a particular group of people. In one study, Schmidt, Urry, and Gugel (1978) found that over 83% of subjects preferred a computer-based civil service test to the traditional paper and pencil test.

Experience

Often confounded with motivation and possibly with test form preference is prior experience. Currently we do not know what, if any, effects prior experience may play in a computerized testing situation. Will playing arcade games improve a person's score relative to one who has not played those games? What if the computerized test is measuring reaction times? It would seem logical that if a subject was a practiced arcade game player he/she might have an advantage at performing tasks due to familiarity with the testing apparatus. Intuitively, experience with computers, keyboards, display terminals would be expected to affect performance in a testing situation.

The question of the role of prior experience is particularly important in the consideration of computer adaptive testing in young populations. Motor control, particularly fine motor control, is extremely variable with young children. Performance on a computer-based test requires some amount of fine motor control, and the degree to which the child has had the opportunity to develop such prerequisite skills seems likely to influence the outcome of the testing. Otherwise, you may have a child with limited motor experience performing an unfamiliar task on an unfamiliar piece of hardware. Such a condition seems unlikely to provide a valid assessment of any cognitive skill.

Anxiety

Anxiety is another psychological trait of interest. Almost no research has yet been reported for children's computer anxiety and its effects on testing, but at least one situation can be forseen. Tailored testing, or CAT, makes possible the adaptive adjustment of a test's difficulty based upon the subject's performance. A danger in this procedure becomes apparent when a low ability subject suffers several failures on the initial test item as the program is attempting to locate the subject's ability level. Imagine also that the same subject is additionally test anxious. The resulting combination of successive item failure and high anxiety might result in an abnormally low estimate of the subject's true ability level.

In summary, computer-based testing involves several very important issues in testing as well as the conventional psychometric issues inherent in conventional paper and pencil tests. These include issues of prior experience, motivation, motor development, and personality traits such as test anxiety or computer anxiety.

So where can computer-based mental testing be most efficiently be put to use? Hunt and Pellegrino (1984) have evaluated some of the new directions in which computer-based testing might proceed. They classified various intelligence dimensions as verbal ability, spatial-visual ability, and logical reasoning and discussed how computer-based testing might be used. They suggested that computer-based testing is probably not a good candidate for

assessing verbal abilities because current testing methods (i.e., reading and comprehension tests) are reliable, valid, and inexpensive. Computerizing these tests would not initially result in a more accurate assessment of the ability.

In the area of spatial-visual intelligence, these researchers suggest that computer-based testing could considerably expand our ability to measure this domain by presenting dynamic visualizations, geographic orientation, and perceptual illusions. Finally, in the area of logical reasoning, these researchers suggest that computer-based testing is a logical choice for tapping cognitive processes such as problem solving and analogical reasoning, or for presenting abstract stimuli for testing concepts such as Sternberg's notion of non-entrenchment (1982). However, in a search of the literature, no studies were identified that addressed computer-based testing of cognitive abilities in young children. It would appear, therefore, that investigations of the feasibility and effects of computer-based assessment of cognitive abilities, such as analogical reasoning, among early childhood populations represent a serious gap in the current knowledge base. For the remainder of this paper an exploratory investigation of computer-based testing of analogical reasoning conducted with young children which addresses this gap will be briefly discussed.

A Study of the Computer-Based Assessment of Analogical Reasoning in Kindergartners and Second Graders

To date, there have been a number of research studies that have focused on determining the development and nature of analogical reasoning in adults (Mulholland, Pellegrino, & Glaser, 1980), older children (Alexander, White, Haensly, & Jeanes, 1986), and preschoolers (Alexander, Willson, White, Fuqua, Clark, & Wilson, 1987). In one of these investigations (Alexander, Willson, White, & Fuqua, 1985), the research led to the development of a rule hierarchy that nonanalogical reasoning preschoolers used in solving geometric analogy problems. This study suggested that for preschoolers not reasoning analogically, reasoning was systematic and purposeful, although naive in structure. While the rule hierarchy identified characteristics of nonanalogical reasoners, it did so under the constraint of item selection as opposed to item generation. In the previous research, the child was required to select the answer from one of four choices provided. Therefore, to date, analogy research has not critically evaluated the strategies young children use in generating solutions to analogy problems.

In the current investigation, it was felt that by altering the experimental procedure to require the examinee to generate rather than select a response, that the findings would contribute to the identification of the basic nature of analogical reasoning in early childhood populations. That is, by requiring children to construct their response to an analogy problem presented on a microcomputer, a more sensitive measure of their reasoning could be obtained. Moreover, by using a microcomputer as the testing medium, children's reactions to microcomputer-based standardized tesing could be investigated in this young population.

It was the purpose of the study to explore how young children structure and solve geometric analogy problems presented on a microcomputer. Three general research questions were addressed:

1. Can kindergartners and second graders construct responses to geometric analogy problems using a microcomputer?
2. Do they differ developmentally in their patterns of errors for incorrect responses?

3. Do paper and microcomputer versions of an analogy test differ in their effects on each other?

Method

Subjects Twenty-four kindergartners and twenty-four second graders from three private day schools in the Houston area comprised the study samples. The children tended to come from middle class or upper class socioeconomic levels and were predominantly white, although there were Black, Asian, and Hispanic children included. All children from one school were classified as gifted, and intelligence test scores were generally above 120 on the WISC-R or an equivalent test.

Instrument For this investigation a microcomputer version of the Test of Analogical Reasoning in Children, or TARC (Alexander et al., in press), was developed. The TARC is an individually-administered test of analogical reasoning containing 16 geometric analogy problems of the type, A:B::C:?. The 16 items are composed of familiar geometric terms varying on the dimension of shape (square, triangle, circle, square), color (red, blue, yellow), and size (large, small). The TARC occurs in three versions: a game version, a lifesize paper and pencil version, and a reduced (i.e., reduced-sized) paper and pencil version. The microcomputer version of the TARC, or MICRO-TARC, was a variation of Form A of the TARC. In this variation, children were presented each of the 16 items on the CRT. Beneath each item, the computer displayed eight black geometric figures; that is, all possible shape and size combinations from the TARC. In addition, the three choices for color were also presented on the screen. The subject was required first to select a figure from the 24 possibilities displayed and then to make selection as to the color for that figure.

Procedure The 24 kindergartners were randomly divided into four equal groups in a Solomon four group design. The first group was administered the MICRO-TARC. The second group was administered only a reduced paper and pencil version of the TARC Form A. The third group was administered the MICRO-TARC followed one week later by the reduced version. The fourth group was administered the reduced version followed one week later by the MICRO-TARC. The 24 second graders were tested only with the MICRO-TARC.

All testing was conducted individually by the first author, and all subjects were required to successfully complete a short prescreening program on the computer prior to testing with the MICRO-TARC to ensure that they could manipulate the computing apparatus.

Results Total test scores for both the reduced and microcomputer version of the TARC were corrected for chance prior to statistical analysis. Error analysis was performed on incorrect solutions to the MICRO-TARC items by transforming the scores into three binary variables corresponding to the three item dimensions: size, shape, and color. Error scores were additionally standardized to facilitate comparison among the subjects. Results of the analyses conducted on the first pair of research questions evaluated the performance and errors made by the kindergartners and second graders separately. These results suggested that kindergartners were performing at almost random levels on the MICRO-TARC, while second graders were performing at levels significantly above those of the kindergartners. Moreover, the errors made by the kindergartners were

different from those made by the second graders. Kindergartners' performance decreased ordinally with complexity of choice of stimulus from two (size) to three (color) to four (shape), while second graders' performance was independent of complexity of stimulus.

Statistical analysis of the second pair of research questions directly examined the group differences identified in the first pair of research questions. A significant group difference between the kindergartners and second graders was verified as second graders outperformed the kindergartners on the MICRO-TARC. These analyses further suggested that the errors committed by the two groups were different. Second graders made approximately the same number of errors over the dimensions of color, size, and shape. Kindergartners, by comparison, made more errors on the more complex dimensions, as supported by linear trend by group contrasts.

Analysis of the third pair of questions focused directly on the kindergartners' performance on the reduced and microcomputer versions of the TARC. Pre- and posttest means are given in Table 1. T-tests for pretested versus unpretested groups were performed for the posttest administration of both the microcomputer and paper TARC.

Table 1

Means and Standard Deviations for Micro and Paper TARC

Group	M	SD
Group #1		
MICRO-TARC only	-0.6250	0.4082
Group #2		
Paper-TARC only	-0.8333	1.1751
Group #3		
MICRO-TARC pretest	0.2083	0.6325
Paper-TARC posttest	0.5000	2.5298
Group #4		
Paper-TARC pretest	6.5000	3.3466
MICRO-TARC posttest	5.0417	3.7103

These analyses suggested that the MICRO-TARC was significantly more difficult for the kindergartners than the reduced paper and pencil version. In addition, a positive effect for taking the paper version prior to taking the microcomputer version was found, but the effect for taking the microcomputer version prior to the paper version of the test was ambiguous. It appears that the paper test only group was unusually inept in performance on the TARC, even though randomization was applied. Thus, it appears that their performance was lower than might be expected. Examination of the two groups given both versions of the TARC shows that effect on the paper version

of the initial microcomputer version is extremely deleterious. Thus, no firm conclusion can yet be drawn.

Discussion The specific results of this study are of interest to cognitive and developmental psychologists. Constructing responses to geometric analogy test items appears to be more difficult than selecting a response from a limited number of alternatives. Between the ages of five and seven there appears to be an improvement in children's cognitive processing of complex stimuli so that they can construct responses independently of the number of alternatives within attributes of color, size, or shape.

Of importance to those interested in computer-based testing were a number of results of this study. First, children in kindergarten, whose age ranged from 4.7 to 5.9, uniformly were able to use a joystick to manipulate objects on a computer screen. Second, the amount of information presented on the screen was too great for kindergartners to process well; second graders did not have difficulty with the cognitive load. Third, the computer version of the test, requiring a construction, was significantly more difficult than a paper version of the test. Although the tasks were not strictly parallel, there is no reason to believe that children would perform differently on strictly parallel tasks whether on computer or paper, however.

The MICRO-TARC geometric analogies test is a prototype of intelligence tests being developed by companies and individuals around the country. It is one of the first such tests to be examined, and its success is an important contribution to the advancement of computer-based testing, especially of young children.

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ENCODING AND RETRIEVAL PROCESSES IN THE SPATIAL MEMORY PERFORMANCE OF ADULTS

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In the past 20 years, intellectual and academic assessment have come under heavy public scrutiny and have been the topic of numerous strident debates in local school districts, state legislatures, and universities. The impact of testing upon students, their schools, and ultimately their society, has been the cause of much concern and some outrage. While it would be foolhardy to represent the mass of academic wisdom and public opinion regarding any aspect of this domain as having reached consensus, two propositions enjoy fairly general support (a) the process of education requires testing, and (b) our schools need better tests.

Nowhere is the need for better tests more keenly felt than in the field of intellectual assessment. Intelligence tests have advanced little from Binet's initial efforts. Two possible reasons for this situation are (a) the lack of an adequate theoretical base for testing, and (b) the failure of standard testing procedures to provide sufficient information for meaningful assessment. Anchoring tests to theoretical frameworks would provide a basis for choosing appropriate tasks and for examining and interpreting individual performance on those tasks. The development of intelligence tests, however, has been driven more by the empirical concerns of psychometrics than by any theoretical view of cognition. In general, intelligence tests are made up of individual tasks that are characterized more by psychometric integrity than by theoretical consistency. By relating and contrasting performance across a variety of experimental tasks, test developers have produced IQ measures that separate individuals along underlying continuous dimensions. While this approach has improved our ability to categorize students into groups, it provides little direct information about how to instruct the students once such grouping decisions have been made. Meaningful assessment is further hampered by the tendency of test developers to focus on the products of cognition rather than on the processes. The emphasis on "how much" (i.e., the number of items correctly answered) is in part a function of the amount of time an examiner is able to allocate to the evaluation of any one child's performance and in part to the difficulty associated with trying to collect data illustrating "how" a child responds. To some extent, then, expedience and the limited capacity of the human information-processing system constrains the data collection process. The relative absence of qualitative data, however, has not discouraged test developers and administrators from treating quantitative data as if it were qualitative. That is, data from IQ and achievement tests are often interpreted to indicate that a child has an "attention" problem or has difficulty in processing information "sequentially" or "simultaneously." In turn, information about inferred processing problems is often used by school psychologists in making decisions about how children should be taught.

While the accuracy of children's responses can be informative and useful in determining how well children perform relative to their peers, detailed information about the nature and speed of responding allows examiners to generate programmatic hypotheses specific to individual children.

Advances in cognitive psychology provide a potential theoretical base for the improvement of intellectual assessment. Information-processing researchers have developed detailed models of how people accomplish intelligent acts such as learning from the environment and solving problems posed by the environment. In contrast to the approach of test developers, information-processing psychologists have stressed the role of assessment in instructional planning and delivery (e.g., Belmont & Butterfield, 1977; Brown, in press; Pellegrino & Glaser, 1979; Ryan, 1981).

Recently, there have been attempts to address the theoretical shortcomings of intellectual assessment and to capitalize on the advances in contemporary cognitive psychology. The Kaufman Assessment Battery for Children (K-ABC) is a prominent example. Kaufman (1983, p. 108) asked, "Shouldn't intelligence tests be based on current theories rather than on arbitrary selections of tasks developed sixty to one hundred years ago?" Kaufman and Kaufman (1983) answered by setting out to measure intelligence "from a strong theoretical and research basis" (p. 5). The relative success of this venture has great import for educational practice because intelligence tests are critically involved in decisions that determine where students are placed and how they are taught.

Although the development of the K-ABC was intended to address the adequacy of the theoretical basis for testing, it does not appear to have addressed the adequacy of the information derived from testing. The K-ABC is administered and scored in the traditional manner. As with other individually administered intelligence tests, K-ABC tasks are presented by a psychologist who observes and scores the child's performance. As is typical of these tests (as well as of group administered intelligence tests and most other academic ability and achievement tests), student's performance is reduced to a single bit of information - right or wrong - for each item attempted. Item scores are then aggregated into raw scores for tasks, subscales, and scales that are converted to standard scores that indicate a student's standing relative to a norm group. While this approach adequately characterizes *how well* an individual does relative to the norm group, it provides little indication of *how* the individual does it. The focus on cognitive products rather than on cognitive processes provides little information of diagnostic value.

Traditional Versus Technologically Aided Data Collection Procedures

It might be argued that traditional testing procedures constrain the task so that no more accurate or detailed information can be collected. Several of the K-ABC tasks, for instance, are sufficiently challenging that simply presenting the items, observing the student's response, classifying the response as correct or incorrect, and applying the appropriate stopping and continuation rules, can tax the information processing resources of the test administrator. The Spatial Memory subtest of the K-ABC is such a task. In the present experiment, a microcomputer was used to ease the burden of task administration and to improve the nature of the information collected. The microcomputer timed the stimulus presentation interval, and was used to store detailed records of exactly what the student did on each item and how long it took. From this detailed data base, reasonable inferences about

the nature of the cognitive processes and strategies that underlie a student's performance can be drawn.

In addition to providing potentially valuable assessment information, these data can be used to test empirically, and at a more detailed level than factor analysis of simple performance measures permit, the validity of the theoretical assumptions underlying the K-ABC. The K-ABC purportedly is based on a "convergence" of theory and research in cognitive psychology and neuropsychology supporting the assertion that human cognitive processing can be classified as essentially simultaneous or sequential. Kaufman and Kaufman cite specifically the work of Neisser (1967) and Schneider and Shiffrin (1977; also Shiffrin & Schneider, 1977). This processing dichotomy is the foundation for interpreting results from assessment and for planning educational programs using the K-ABC and its companion instrument, the Kaufman Sequential or Simultaneous (K-SOS).

While Kaufman (1983) argues that Neisser and Schneider and Shiffrin's conceptualizations of cognitive processing are convergent, Neisser's (1967) distinction between parallel and sequential processes and Schneider and Schiffrin's (1977) characterization of automatic vs. controlled processing reflect quite different models, neither of which appears closely aligned with the simultaneous-sequential dichotomy underlying the K-ABC. There is, however, one area of convergence between Neisser and Schneider and Shiffrin. Studies reviewed by Neisser and studies conducted and reported by Schneider and Shiffrin focused on response time as crucial in determining the nature of underlying processing. If response time increased with stimulus complexity or information load, processing was said to be sequential or controlled. If response time was independent of stimulus complexity, processing was characterized as parallel or automatic. In the present study, we used a microcomputer to help us collect several response times and to preserve touch sequences in an attempt to determine whether or not more detailed information would corroborate the Kaufman's contentions regarding simultaneous processing. If Kaufman and Kaufman's (1983) notion of simultaneous processing is based on Neisser's parallel processing and Schneider and Shiffrin's automatic processing, and if spatial memory is a simultaneous processing task, then response times should be independent of stimulus complexity once motor speed is controlled.

Outline of the Present Study

The study reported in this paper is the first in a series of studies designed to determine how children store and retrieve information from a spatial memory task. On the spatial memory subtest of the K-ABC, children are presented briefly with a page displaying several pictures of familiar objects in an array. The array is then replaced by a grid and children are asked to point to the locations where the pictures had been. Children's performance on this task is interpreted as a measure of proficiency at "simultaneous processing," one of the two components of general intelligence proposed by Kaufman and Kaufman (1983). The objectives of this research are (a) to develop procedures and technologies that permit detailed and precise measurement of performance on spatial memory tasks, (b) to test the K-ABC's simultaneous processing hypothesis for spatial memory performance against an information-processing analysis, and (c) to develop a detailed model of the cognitive structures, processes, and strategies involved in the solution of spatial memory items.

Although the K-ABC is normed for children 2 1/2 to 12 1/2 years old, initial research efforts have examined the performance of adult subjects.

Adult subjects were chosen because (a) young children are less aware and/or less able to report how they perform a task and (b) analysis of adult performance will provide a developmental contrast for subsequent studies with children.

Method

Subjects

Subjects for this study were 28 (14 males, 14 females) undergraduates at Texas A&M University. Subjects were tested and interviewed individually.

Materials and Apparatus

Materials for this research included the standard spatial memory task materials (i.e., sets of stimulus and response cards) from the K-ABC. On each stimulus card, several (2 to 7) familiar objects (e.g., apples, birds) are arrayed in various locations. The response cards present a grid of squares configured in either a 3 X 3, 9-square matrix or a 3 X 4, 12-square matrix. A second set of stimulus cards was constructed for the motor task. These cards presented two to seven black boxes within one of the two test grids (3 X 3 or 3 X 4) of the spatial memory task. Interview coding sheets were used to record interview responses. In the present study, a Commodore 64 was used to regulate presentation time for the stimulus plates, to collect response times, and to record the sequence of pointing responses. In addition, a video recorder was used to provide a back-up record of response sequence and post-task interview.

Procedure

Procedures for the first phase of this study were kept as close to the standard administration procedures of the K-ABC as possible. Deviations from K-ABC administration procedures were introduced only where it was necessary to obtain information from the subject for the purpose of evaluating the validity of the simultaneous processing claim.

Each subject viewed and responded to all 21 stimuli in the K-ABC spatial memory task. For each item, an experimenter pushed a button starting an internal clock in the Commodore 64 as he or she exposed the stimulus card. When the five second exposure period had expired, the computer emitted a beep, at which point the experimenter exposed the response card, simultaneously pressing a button to start a second clock. Subjects were instructed to rest their hand on a button during the presentation of the stimulus card. After the response card had been presented, subjects removed their hand from the button, pointed to the squares that corresponded to the location of the objects, and returned their hand to the button. When the subject initially touched the stimulus card, the experimenter pressed a button, registering the time to first touch. For each trial, the computer recorded three times (a) release time (from exposure until the subject removed his or her hand from the button), (b) first touch time (from exposure until the subject initially touched the response card) and, (c) total time (from exposure until the subject returned his or her hand to the button). As the subject pointed to the response card, a second experimenter recorded the sequence of squares to which the subject pointed using a designated section of the Commodore 64 keyboard in which each key corresponded to one of the response squares.

Immediately after completing the spatial memory task, subjects were interviewed concerning their performance on the task. Initially they were asked a general question about how they remembered the locations: "Is there anything you did to help you remember where you saw the objects?" They were then asked for each item beginning with the final item, how they remembered where they had seen the objects.

Finally, the subjects were given a perceptual-motor task designed to control for individual differences in motor speed and for the extra time physically required to point to more squares. In this task, each item was comprised of a single card. In a 3 x 3 or 3 x 4 matrix identical in size to the response cards of the K-ABC spatial memory task, varying numbers of squares contained black boxes. After viewing a card for five seconds, subjects were to remove their hand from the button on an auditory cue from the computer, point to each square that contained a black box, and return their hand to the button. Release, first touch, and total times and response sequence were once again recorded.

Results

Major issues under investigation in the present study include (a) is performance on the spatial memory task of the K-ABC best viewed as an index of simultaneous processing ability? and (b) does a simple measure of correctness of response, such as collected in the standard administration of the K-ABC, represent an adequate data set for educational and psychological interpretation of performance? In the following section, converging lines of evidence from analysis of number of locations recalled correctly, response times, and verbal report of subject strategies are summarized to examine these two issues.

Response Accuracy

For each subject, data from 21 spatial memory plates were collected. This represented a total of 588 possible items for which correctness of response could be judged. Five hundred seventy-five (98%) of the possible items were available for analysis. The remaining 13 items were lost due to computer malfunction or experimenter error. Evaluating the 575 responses according to the standard dichotomous scoring method suggested for the K-ABC, resulted in 519 (90%) correct responses across all subjects. This represents a clear ceiling effect, reflecting the fact that this was a task for children administered to adults. Analyzed differently, however, the adult data are not uninformative relative to the question of whether or not a simple correct/incorrect judgement masks information that might be useful for interpreting performance on this task.

For each of the 21 plates, it is possible to perform more detailed analyses of correctness. Subjects were asked to recall and to touch between 2 and 7 locations on a blank grid. By preserving the touch sequence, we can generate scores reflecting approximations to correct performance across all items. Judging correctness in this fashion, subjects touched correctly 2475 out of 2546 (97%) possible locations. The difference between dichotomous and more detailed analysis of responding was even more dramatic when considering performance for only the last seven plates. The last seven plates (15-21) represent the most informationally complex arrays and contain 48% of the total possible correct touches. In addition, these last seven plates contained 97% (83 of 86) of all errors of omission and 94% (51 of 54) of all errors of commission. When scored dichotomously, 72% (138 of 191) of the

responses to those plates were correct. Using the more detailed analysis, however, it was found that subjects pointed to 93% (1143 of 1226) of the total possible correct locations. From the detailed analysis, it was also noted that when subjects made errors, they tended to maintain or approximate the correct number of touches. That is, for the 53 plates on which errors occurred, subjects pointed to the correct number of locations 26 (49%) times. Subjects pointed to the correct number of locations (plus or minus 1) 49 (92%) times.

Response Time

Three measures of response time were collected during the spatial memory and motor tasks. For the memory task, release time and time to first touch were not strongly related to stimulus complexity, $R^2 < .02$. Total response time, however, was sensitive to stimulus complexity. The simple correlation between total time and grid size was .37 and between total time and number of locations to be recalled was .69. When between subject variance was removed (see Anderson, Mason, & Shirey, 1984), it was found that grid size accounted for 19% of the within-subject variance for total time and number of correct locations contributed an additional 46%. Thus, the two indices of stimulus complexity accounted for 65% of the within-subject variance for total time on the memory task.

The means and standard deviations for total time on the memory and motor tasks can be found in Table 1. As can be seen, the difference between memory and motor total times increases with the complexity of the stimulus array.

Table 1

Mean total time for memory and motor tasks as a function of grid size and number of objects

Variable	Task				
	Memory (sec.)	S.D.	Motor (sec.)	S.D.	Difference (sec.)
Grid Size (3 X 3)					
# of Objects					
2	2.334	.550	1.830	.392	.504
3	2.594	.552	2.037	.462	.557
4	3.082	.634	2.446	.570	.636
5	3.310	.659	2.635	.526	.675
Grid Size (3 X 4)					
# of Objects					
2	2.176	.413	1.770	.362	.406
3	2.649	.597	2.034	.393	.615
4	2.868	.525	2.281	.429	.587
5	3.763	.987	2.649	.504	1.114
6	3.993	1.023	2.853	.558	1.140
7	4.337	1.050	3.153	.616	1.184

Interview Data

Interview or introspective data have been characterized as useful for discovering psychological processes but unreliable for describing and verifying the specific characteristics of those processes (Nisbett & Wilson, 1977). Thus, verbal reports are often viewed as sources of interesting but suspect information that needs to be verified against objective performance measures. Ericsson and Simon (1980), taking a contrary position, argue that verbal reports are data and suggest that reliable and informative verbal report data is a function of a) how close in time subjects are interviewed following completion of a task, and b) whether or not the requested information requires subjects to infer rather than remember specific mental processing sequences.

In the present study, we attempted to follow the general guidelines offered by Ericsson and Simon (1980). Subjects were interviewed directly following completion of the spatial memory task starting with the most complex and most recently seen plate (#21) and working backwards through less informationally complex plates to the beginning. Subjects were asked to recall if there was anything in or about the array that helped them to remember the locations of objects. Table 2 summarizes data on the correspondence between touch pattern responses and verbal reports of how information was organized for retrieval for the last six plates. There was agreement between 141 of the 152 (93%) coded responses for plates 16 through 21. These six plates represented the most complex informational arrays of objects presented at the closest point in time to the interview. On the basis of the high percentage of agreement between performance and verbal report of performance, a further analysis of the interview data was judged to be warranted.

Table 2

Percentage agreement between touch pattern responses and verbal reports for adult subjects on plates 16, 17, 18, 19, 20, and 21

Plate No.	Agreements	Disagreements	$\frac{A}{A+D} \times 100\%$
21	22	3	88%
20	25	1	96%
19	25	2	93%
18	24	2	92%
17	24	1	96%
16	21	2	91%
Total*	141	11	93%

* Agreements could not be determined for 16 touch pattern responses because subjects responded "don't know" in the interview.

Table 3 summarizes the percentage of interview responses by category. Subject responses were classified into one of six strategic categories: rows, columns, corners, diagonals, shapes, or other. When subjects could not

remember how they organized information for a specific plate, strategy use was classified as don't know. In cases where subjects reported the use of more than one strategy, all responses were coded.

Use of a row or column strategy meant that subjects tried to chunk information by row or by column to help them remember the location of items in an array. For example, subjects using a row strategy might remember one of the final items on the test by recalling that there were three objects in the first, second, and fourth positions of the first row, two objects in the middle of the second row, and two objects in the first and last positions

Table 3

Percentage of Interview Responses by Category

Plate No.	No. of Objects	Total Responses	% Rows	% Columns	Rows + Col.	% Corners
			Grid Size: 3 X 4			
21	7	32	44	25	69	9
20	7	35	37	20	57	9
19	7	32	44	28	72	0
18	7	34	41	29	71	6
17	6	36	33	17	50	8
16	6	32	50	19	69	0
15	5	30	27	13	40	3
14	3	30	20	17	37	0
13	4	32	16	6	22	9
12	4	29	14	0	14	0
11	2	29	31	0	31	0
Mean			32.41	15.84	48.24	4.08
			Grid Size: 3 X 3			
10	5	32	9	59	69	6
9	5	32	3	72	75	19
8	5	32	9	16	25	0
7	3	30	10	0	10	7
6	4	32	0	50	50	3
5	4	30	0	3	3	87
4	2	30	0	0	0	0
3	2	29	3	48	52	7
2	3	29	90	0	90	0
1	2	29	0	76	76	0
Mean			12.50	32.43	44.93	13.17
Grand Mean			22.93	23.74	46.67	8.41

Table 3 (continued)

Percentage of Interview Responses by Category

Plate No.	% Diag.	Corners + Diag.	% Shapes	% Other	% Don't Know	Other + D.K.
			Grid Size: 3 X 4			
21	3	13	9	9	0	9
20	6	14	23	3	3	6
19	0	0	19	3	6	9
18	3	9	12	3	6	9
17	14	22	19	3	6	8
16	6	6	9	0	16	16
15	3	7	13	17	23	40
14	7	7	13	33	10	43
13	16	25	50	3	0	3
12	3	3	76	7	0	7
11	0	0	0	48	17	66
Mean	5.54	9.62	22.19	11.76	7.89	19.65
			Grid Size: 3 X 3			
10	0	6	13	6	6	13
9	0	19	3	3	0	3
8	0	0	72	3	0	13
7	0	7	73	10	0	10
6	0	3	41	6	0	6
5	0	87	10	0	0	0
4	53	57	0	40	3	43
3	0	7	0	31	10	41
2	0	0	0	10	0	10
1	0	0	0	17	7	24
Mean	5.33	18.50	21.15	12.74	2.68	15.42
Grand Mean	5.44	13.85	21.69	12.23	5.41	17.63

of the third row. As can be seen in Table 3, the use of a row or column strategy was predominant when there were six or seven objects to be recalled on the 3 X 4 grid or 5 objects to be recalled on the 3 X 3 grid. It would appear that these sequential processing strategies are more likely to be used when subjects recognize that increasing stimulus complexity requires systematic organization of information if spatial locations are to be recalled accurately.

Corner and diagonal strategies tended to be used as secondary information organizers. For instance, a subject might chunk information according to a general row or column strategy and then note that items in the first or last rows were in corners or that items in two rows were juxtaposed diagonally. For only two plates, numbers 5 and 4, were corner or diagonal strategies cited as the primary organizational aid. In plate 5, the four locations to be recalled were the four corners, and in plate 4, the two locations to be recalled formed a diagonal from the center to the lower right corner.

Shapes or form was the only other major strategy mentioned as an aid to recall. In general, shape strategies were used as secondary organizational sources for plates with high stimulus complexity (6 or 7 locations to be recalled) and primary sources of recall for plates of moderate stimulus complexity (3, 4, or 5 locations to be recalled). One or two objects do not represent enough locations to form recognizable shapes. Six or seven locations, on the other hand, represent enough data points that simple shapes such as boxes are not readily apparent unless the locations happen to be in straight lines such as the five data points included in the "X" in plate 20.

Finally, only about 17 percent of the responses were coded as "other" or "don't know." Responses such as "straight line" with no accompanying locator information (e.g., "in the middle" or "that one was just easy") were classified as other or don't know, respectively. These responses typically occurred in situations of low stimulus complexity and generally reflected the fact that little or no effort was required by the adult subjects to recall locations in these arrays.

In summary, examination of the interview data is consistent with the interpretation that (a) subjects report the use of a variety of reasonable strategies for remembering locations, (b) many of these strategies are inherently sequential (e.g., row and column strategies), and (c) strategy reports can often be directly verified against response sequences.

Discussion

The present study illustrates the utility of computer assistance in test administration and scoring. Through the use of a microcomputer, detailed information about students' performance was collected. The picture of cognitive functioning that can be developed from this enriched data base contrasts sharply with that drawn from simple dichotomous scoring and with the view on which the K-ABC is based. The results of this study may be interpreted to suggest that, at least for adults, performance on a spatial memory task cannot be characterized adequately by simple measures of response correctness nor described accurately as the result of simultaneous processing. A detailed analysis of performance revealed that even where subjects made mistakes, their performance was reasonably accurate with respect to the number and location of objects they had seen. If a dichotomous summary of the data were sufficient to account for all relevant response variance in performance, one would not expect to find widely discrepant response summaries upon detailed analysis of performance. Said more directly, simple and detailed performance protocols should be congruent if reliable interpretation of subject data is to be discerned. Analysis of adult data suggests an interpretation that subjects would be less likely to be characterized as deficient, different, or deviant in their ability to recall spatial locations following a detailed as opposed to a dichotomous analysis of correct responses.

Analysis of response times and subjects' verbal reports failed to provide evidence for the contention that Spatial Memory is a simultaneous processing task. Performance on the Spatial Memory subtest of the K-ABC is said to be most correctly defined in terms of a child's ability "to mentally integrate input simultaneously" (Kamphaus, Kaufman, & Reynolds, 1985, p. 178). This would mean that at the time of recall, no systematic search of short-term memory is necessary to ensure accuracy. Since information encoded simultaneously would exist in working memory as a chunk or unit, no manipulation of the information would be necessary for accurate retrieval to occur if time limits for memory traces in short-term store were not exceeded. In an integrated unit, even items in an informationally complex array should be equally available for recall. For subjects in this study, response times increased with item complexity in a manner that cannot be accounted for in terms of motor responses nor easily reconciled with the simultaneous processing assumption. Under the assumption of simultaneity, controlling for motor speed in total response time should have resulted in constant decision times across information loads. This was clearly not the case in our data. As information load increased, the difference between motor and memory task times and the variance associated with those times also increased. We would interpret this to mean that subjects needed more time to respond to complex arrays because retrieval was guided by systematic search. Consistent with this interpretation was subjects' verbal reports citing the use of a variety of organizational strategies to aid recall.

In a task such as spatial memory, the question of whether processing is parallel or sequential might reasonably be asked with regard to input, output, and central processing (see Das, Kirby, & Jarman, 1975; Luria, 1973; and Neisser, 1967 for discussion of these topics). While the present study focused only on direct assessment of output or retrieval processing, other memory research (e.g., mnemonics, encoding specificity) and interview data from this study support the notion that processing during input is consistent with, and provides a retrieval plan for, output. Presumably, by planning interventions based on presenting information sequentially or simultaneously, the K-ABC gives indication that the simultaneous vs. sequential distinction applies to processing at input. We view this as problematic for the K-ABC, however, as the locus of the distinction has not been made clear. As would be expected, each of the sequential processing tasks requires sequential recall of sequentially presented stimuli. What creates confusion, is that many of the simultaneous tasks also involve sequencing. For example, the Photo Series task requires the proper sequencing of pictures depicting some event and Magic Window requires identification of objects presented "sequentially" as they move past a window that reveals only a portion of the picture at any one time. To establish more clearly the nature of sequential and simultaneous processing on the K-ABC, we would argue that research investigating processing time during input is needed.

Further, it should be noted that refinements in computer assisted administration should provide still more accurate and detailed assessment information. The technology employed in the present experiment was relatively crude. It is possible that the failure of two of the response time measures employed in present study (release and first touch time) to relate to stimulus complexity may have been caused by experimenter produced error as the experimenter presents the test grid and controls the response clock. We are currently developing a completely automated version of the task in which the stimuli and test grids are presented on the computer

monitor, and students indicate where they saw the objects by pointing to the monitor screen with a light pen.

In summary, investigation of spatial memory is important for educational practice given the impact that the K-ABC and the K-SOS are beginning to have on educational placement and programming decisions in schools. The present results appear to contradict the assumption underlying the K-ABC and K-SOS, that performance on memory and other cognitive tasks can be reduced to simplistic explanations characterized by the simultaneous/sequential processing dichotomy. They also may be interpreted to suggest that further research designed to provide a detailed, information- processing account of performance on spatial memory tasks may help us to better understand children's cognitive functions.

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AN ILLUSTRATIVE APPLICATION OF MICROCOMPUTER TECHNOLOGY TO THE STUDY OF READING

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A cognitive analysis of reading stresses the active role of the reader who allocates attention to critical content areas, monitors comprehension of text information, and employs strategies for remediating detected comprehension failures (Baker & Brown, 1984; Brown, 1980). While there has been a proliferation of studies in this area, the majority of investigations have relied on indirect measures of metacognitive functioning. For example, readers' verbal report of their cognitive activities has been used as a primary indicator of strategy use and comprehension monitoring. However, validity of many of these verbal report procedures has been questioned (Ericsson & Simon, 1980). Verbal report methodologies may not accurately represent how readers process text material, but rather how they "think" they read. Other investigators have used observational procedures to infer readers' text processing behaviors. These procedures also are limited in terms of the range of behaviors that may be effectively monitored. For example, pupils may appear to be attentive when, in fact, they are daydreaming. In contrast, microcomputer technology enables researchers to directly assess a variety of reading behaviors.

To explore the potential application of microcomputers to the study of reading, a series of investigations have been conducted at Texas A&M (Palmer, Kueker, & Stowe, 1985a, 1985b; Palmer, Stowe, & Kueker, 1986). These studies have been concerned primarily with on-line assessment of good and poor readers' strategic reading behaviors. The purpose of this paper is to describe the methodology used in these studies as an illustrative application of microcomputer technology for the study of reading. Topics to be addressed include: (a) presentation of experimental tasks; (b) data collection with microcomputers; and (c) data analysis.

Presentation of Experimental Tasks

Text Materials. A variety of texts were used in our studies of good and poor readers. These texts ranged from 100 word paragraphs (narrative and expository), to 250 word narrative stories of graded difficulty and 900 word passages selected from biological science texts and professional journals. To examine the effect of text manipulations on youngsters' reading behavior, we experimentally manipulated text variables such as word difficulty, clarity, sentence structure, content, and semantic consistency.

The Commodore 64 microcomputer was used to present text and collect data; the procedure for presenting text on the computer screen evolved during the course of the three experiments completed to date. The first computer program presented one line of text at a time, centered in the middle of the computer screen. The subject controlled the presentation of text lines through the use of two buttons labeled up and down. The down button was used to move forward through the text and the up button was

used to look back at previously read text. This method of text presentation enabled us to target the line of text the subject was reading while at the same time allowing the subject to read at his/her own pace.

The method of text presentation was modified for the second experiment due to a concern for its generalizability to printed text. This modification involved reprogramming the computer so that the position of the text line on the computer screen matched its position on a page of text. In addition, a joystick was substituted for the up and down buttons. The subjects pushed forward on the joystick to move through the text and pulled back to reread.

Although the second modification was an improvement, generalizability to printed text was still a concern. Because only one text line at a time was exposed on the screen features of the text such as the beginning and ending of paragraphs were difficult to recognize. To solve this problem, the computer program was modified a third time so as to present a whole screen of text. Incompatible background and foreground colors were used to render the text unreadable, although features of the text were easily recognizable. As the subjects read through the text, the color of the current line being read was changed to make it readable. In this way, pupils' progression through the text could be tracked, while maintaining positional and organizational cues available when reading printed text. The text lines that the subjects read were entered into the program using data statements. However, later versions of the program allowed the text to be entered using a word processor.

Questionnaires. There were two primary purposes for presenting questions in our studies. First, we were interested in pupils' responses to a variety of comprehension questions. For this purpose, a question was presented on the screen and the experimenter's coded evaluation of the pupils' response was made on the keyboard. We were also interested in the role of readers' self and task perception to their reading behavior and their comprehension outcome. To collect these data, questions were presented one at a time on the computer screen. The questions pertained to their own and their peers' attributes as well as to the difficulty of the text. By moving the joystick handle to the right or left, pupils' positioned an arrow to their desired point on the scale, and pressed the fire button on the joystick. The rating was recorded by the computer and the next questionnaire item and corresponding scale was presented on the screen.

Data Collection

As noted previously, a variety of cognitive activities have been associated with readers' understanding of texts. These cognitive skills include: identifying and allocating attention to important information, monitoring comprehension, and taking corrective action when comprehension failures occur. If readers are engaging in these activities it should be reflected in: (a) the amount of time they allocate to text lines; (b) the lines they reread; and (c) their intensity of attention. If text lines contain information that is identified as critical by readers, they may spend relatively more time on these lines, look back at them more often, and read these lines with greater intensity of attention when compared to other text lines. The procedures used to assess each of these reading behaviors will be individually described.

Line Time. Prior to on-line measures of reading behavior, total reading time for a passage or page of text was the primary measure of reading time.

With the development of microcomputers, however, it became possible to measure and record reading time for much smaller units of text. In our research, the Commodore 64 was used to measure the subjects reading time for a 40 character line of text. This was accomplished by allowing the subject to control the exposure time of line of text on the computer screen and measuring this exposure with the software clock in the microcomputer. The software clock of the C-64 has a resolution of 1/60 of a second. Time of the exposure began after the line was printed to the screen and stopped when the subject pressed an up or down button to move to the another line. The program's response time to the subject's touch of the button was instantaneous, making it possible to measure line exposure interval for even the fastest readers with no noticeable delay or inconvenience to the subjects.

Lookback. In order to track pupils' reading of the text, it was necessary to determine if a subject was reading a new text line or looking back and rereading a previously read line. To accomplish this, the number of the line currently being read was compared to the highest line number read by the subject. If the current line being read was less than the highest line read, a one was recorded to indicate a lookback. If the current line was equal to or greater than the highest line, a zero was recorded to indicate a first reading.

Intensity of Attention. A capacity model of attention assumes that a fixed amount of attention is available at any particular time (Kahneman, 1973). This model also assumes that individuals' attention may be allocated to both a primary task and to general monitoring of the environment. With this fixed capacity model, if more attention is allocated to a primary task, less attention is available to monitor other stimuli. For example, the more one is engrossed in reading a novel, the less attentional capacity there is available to monitor your door bell ringing. In our studies, intensity of attention was assessed using a secondary task. In this paradigm, pupils were asked to respond to an auditory signal while engaged in reading. The resulting reaction time to the stimulus is an indication of individuals' unused cognitive capacity and may be used as a measure of learners' cognitive capacity allocated to the reading task, i.e., signal detection time (SDT). Specifically, pupils' were required to respond to a periodic 100 ms tone by pressing the fire button on the joystick. Traditionally, measures of reaction time require a timing resolution accurate to within one millisecond. This presented a problem since the software clock of the Commodore 64 only provides an accuracy of 1/60th of a second. This timing accuracy was further reduced because BASIC, the language used to program the computer, could monitor the joystick fire button only twenty times per second.

To solve this problem a machine language subroutine was designed. This subroutine instructed the interface timers of the 6526 CIA (Complex Interface Adapter) chip to count negative transitions of the two phase system clock which runs at 1 mhz. The machine language subroutine administered the 100 ms tone, started the timers, and monitored the joystick button. When the button was pressed, the timers were stopped and their values stored. A BASIC program read the stored values and saved them to disk. This technique allowed for a time accuracy of approximately 3 microseconds. For our purpose, subject reaction times were rounded to the nearest millisecond.

Data Analysis

The unit of observation for analysis of data was each line read by a subject. The variables contained within each observation included: the observation number, subject ID, number of line assessed, line time, whether the line was a first reading or a lookback, whether a signal detection task was administered and, if so, the latency, a comprehension performance measure, and the reader's perception data. After a subject finished reading a passage, the program constructed a data line for each line of text read by the subject. Each line of data was followed by a carriage return character and stored in a sequential file on a floppy disk. These data files were then uploaded to the university mainframe computer for statistical analysis. A standard modem and modem software were used to upload the data. This technique allowed for a very fast turnaround time between collecting and analyzing the data because coding and entry of the data by hand was eliminated. In fact, hand coding and data keyboard entry would have been impractical, since our largest data set consisted of approximately 40,000 lines.

Future Directions

Using the previously described computer-assisted procedures, we have identified strategic differences in the behavior of good and poor readers. Specifically, while poor readers were attentive to the text and at times used relevant strategies, they did not differentially respond to critical text information. In contrast, good readers targeted their strategic efforts to critical information. Furthermore, good readers' perceptions of their competence, effort, and the difficulty of the text material more accurately reflected their reading behavior and comprehension of the text.

Even if teachers were able to work with pupils on a one on one basis, they would not be able to monitor the variety of behaviors with the accuracy required to identify these reader behaviors. However, with the availability of appropriate computer software and hardware, teachers can receive detailed information on their pupils' reading behaviors daily and modify their instructional activities in view of this information. By design, computers are capable of presenting academic tasks, monitoring students' responses, and providing immediate feedback to students. They also are capable of giving teachers information on student performance. With this technology, teachers will be able to gain a clearer picture of what pupils know and how they attempt to learn school tasks.

Partially as a result of the increased use of microcomputers in the study of human cognition, elaborated artificial intelligence models of text processing will soon be available. With these models and a technology capable of real-time programmable interactions with learners, microcomputers can help children or adults learn how to learn.

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MANIPULATING QUALITATIVE DATA WITH A DATA MANAGEMENT SYSTEM or REPLACING THE SHOE BOX WITH THE MICROCOMPUTER

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So you have just completed your 75th interview and are ready to analyze your data. Each interview produced an average of 50 insightful statements which you have categorized into 36 different topics. (That's 3,750 pieces of information in 36 categories.) Or you have just taken apart the 10 best selling novels of the 50s and of the 80s to see how the depiction of the role of women in our society has changed. Each novel produced approximately 250 notable incidents (or a total of 5,000 separate pieces of data). Or you have had your class of 16 students note in special logs the potential applications of topics covered in class during the semester. Each student came up with at least a dozen comments each week. (This means you have at least 2,800 comments.) How do you manipulate these data so that you can analyze their message and report your findings in a meaningful manner?

Naturalistic studies such as these tend to produce volumes of qualitative data. Traditional number-crunching approaches provide little assistance in the interpretation of such findings. In the past researchers resorted to a variety of strategies for dealing with such huge amounts of information, but they all boiled down to what might be called the "shoe box" approach. For example, some noted each statement on an index card and lined the cards up by topic in boxes or containers of some sort. This definitely was an improvement on the "scroll" approach wherein long sheets of paper or newsprint were covered with written comments regarding distinct topics. Experts at the "shoe box approach" even arrived at the advanced stage of development in which punched holes in special areas of the cards were used to sort the cards mechanically by inserting knitting needles through the holes. However, most of these innovative approaches surrendered to the "photocopy" approach. The ability to copy whole pages of relevant material for 5 cents a copy destroyed one's motivation to write or type each appropriate piece of data on a separate card. The age of technology had definitely put the shoe box in jeopardy.

The microcomputer has ushered in a new era in data manipulation for naturalistic inquiry. For the first time, the researcher is in a position to control the data rather than being limited by its sheer bulk. This new situation is made possible by the large array of word processing and data management programs currently available for most popular microcomputers. Word processing programs allow the user to create text which can be easily modified. Data management programs allow the user to enter data into the computer in a convenient and meaningful format and then to re-arrange it in almost any desired fashion. The key to using microcomputers in naturalistic inquiry is to obtain a word processing system and a data management system that are compatible. These systems are compatible when the information from one can easily be transferred to the other. With this compatibility, the researcher can enter a data set, modify it as needed, re-arrange it, print out selected data for further analysis, create new files of the selected data, and incorporate the selected data into the final report. *Wordstar* and *dBase II* are two compatible software systems. With a microcomputer and software programs such as these, the researcher

can discard all the old shoe boxes and enter the electronic age of manipulating qualitative data for quality reports.

Manipulation of Qualitative Data

Methods of dealing with quantitative data presume that knowledge is unidimensional and generalizable. Individual differences are generally forced to surrender to group means and standard deviations. Naturalistic inquiry, on the other hand, attempts to preserve the individual piece of information. Knowledge is seen as multidimensional and applicable in various ways in various situations. To force data into categories that do not represent the diversity of the real situation is an anathema to naturalistic inquiry.

Yet, there is no way the human brain can attend to thousands of bits of information simultaneously. We have to categorize, we have to group, we have to compare pieces of information. In addition, if we are to be true to the premise that the universe is multidimensional, we must do this categorizing and comparing from a variety of viewpoints. A data management program such as dBase II is an excellent tool for doing these processes because it has the power to hold thousands of individualized bits of information, which are labelled or categorized in a variety of ways, ready for grouping. For example, quotations selected from interviews might be identified by the name, age, location, position, and background of the interviewee as well as the topic, quality, and potential area of application of the quotation. Data management programs allow the researcher to pull from all of the collected quotes those dealing with a certain topic and made by people in a specific position. Review of these data could provide insights regarding the different practices or attitudes on this topic by people in the various positions noted. Resorting the data according to background or location of the interviewee or any of the other identifiers would be a simple matter, and it might present a whole new view of the subject. Such sorting and resorting of qualitative data can be a tremendous aid in respecting the individualistic nature of information gathered through a naturalistic approach.

Moreover, it is not only the collection and analysis of data but also the reporting of findings that can benefit from the use of a dBase program. The design of a study should be consistent from its presumptions and conceptual framework through its methodology and into its reporting of findings. While some descriptive statistics will be helpful in interpreting and reporting findings, it is essential that the individualistic nature of the findings also be respected in their presentation. Reports of data gathered using interviews, for example, should certainly contain selected, insightful quotations from those interviews. The integration of various microcomputer programs simplify such reporting. Appropriate quotations can be selected from the data base and transferred into the report *without any retyping.*

A Data Management System

There are a number of data management systems available for use on the microcomputer. They range from those supplying simple file management functions such as *pfs:file* or *Q & A*, to complex, command-driven systems such as *dBase III*, R:*base 5000*, or *Paradox*. Basically all are designed to hold and manipulate data in a variety of ways. The sorting, combining, indexing, and reporting of data are typical functions; they are done at electronic speed rather than the hand-sort speed of the shoe box.

Judging from experience, there seem to be at least three questions that anyone who wishes to use a data management system for qualitative research needs to ask before selecting a specific program. Is it easy to integrate the system with other programs, especially word processing systems such as *Wordstar*? Will the program allow you to sort and compare data in a variety of ways? How much data will the program handle in total and in individual units? *dBase II* is a versatile program, is widely used, and can serve as a standard against which to compare others in answering these questions.

The first step in entering data into *dBase II* is to create a structure within which the data will be stored. A structure is based on the variables that the researcher wants to use in the study and is tailor designed by the researcher to fit the data and research needs. It will usually include fields for identifiers or categories for grouping bits of information, specific pieces of qualitative data, and variables that relate to the data. Thus, it goes beyond simple indentification of categories as described by grounded theory and includes all the factors that might be used to sort the data or to describe it more fully. The structure can be made flexible enough for researchers to attach comments or personal notes to individual pieces of information for later use. *dBase II* is designed so that each field or variable is given a name and identified as either character, logical, or numeric input. Appropriate functions can be performed on these different types of data. However, one definite limitation of dBase II is that each field is limited to 254 characters; this means that no more than 40 or 50 words will fit in one record. Longer bits of information must be linked together.

In some instances a structure for holding the data is apparent from early in the inquiry; however, in many naturalistic studies new issues and new variables emerge as the study goes on. A flexible system such a *dBase II* allows the researcher to modify the structure, replace information in fields electronically, and combine fields for printing out data or forming new files. However, since these are time consuming and require an advanced knowledge of the system, it may be wise to delay decisions on structure formation until the initial gathering of information has indicated any unforeseen issues that might arise.

Another set of vital decisions that must be made before the actual entry of data can begin relates to the coding of the data. For example, it is at this point that data reduction is most feasible. It seems most logical to enter into the data management system only the meaningful information that was gathered rather than everything that happened or was said. There are various ways of doing this. A study based on audio recordings of interviews could proceed by having a secretary type transcripts of all the interviews, but it would be essential for the researcher to review those transcripts, to select the meaningful data to enter, and to identify each piece of data in some manner so that it can be related to the important categories of the study. Others might see such transcription as needless paper work and

prefer to enter data directly from their tapes or notes, but in this case the process of review, selection, and identification is also essential.

Thus, data management systems can do a number of things that make it easier for the researcher to analyze data. They are excellent sorters of information. All the pieces of information from the total data entered that relate to a specific category can be pulled out for review or for comparison to data related to another category. The data in these categories can be separated according to any of the variables included in the study, or they can be combined in any manner which the researcher might think could be helpful. Those experienced in the analysis of qualitative data can readily see these different perspectives can provide new insights into information garnered in the study. Moreover, it certainly is a lot easier than resorting several shoe boxes full of index cards!

Generating Reports

One outstanding quality of naturalistic inquiry is that it collects rich data that can be incorporated into meaningful and descriptive reports which provide understanding of human actions. The task for the researcher is to select the most insightful information, group it into a sound conceptual unit, and report it in clear language. While the data management system allows for the data manipulation, the word processing system facilitates the generation of the report. Since *dBase II* and *Wordstar* produce ASCII files, information can readily be moved between these software systems. Therefore, quotations selected from interviews, segments noted in the literature, or original descriptions of events can be entered into *dBase II*, manipulated as needed, and copied into another file which in turn can then be inserted into the report through *Wordstar* without any retyping. This not only saves work but more importantly allows the generation of reports which are consistent with naturalistic approaches to research.

Using the *dBase II* system, the following approach could be used for selecting data and incorporating it a the final report. With the "copy" command, all of the information relating to a certain category could be sent to an ASCII file. Exiting *dBase II*, the researcher could switch to *Wordstar* and load the newly created file. Although the file could be viewed on the screen, at this point many prefer to print a hard copy of the selected material. Viewing materials on the screen and analyzing the same material on a printed, paper copy seem to be different processes. Reviewing several sheets spread out on a desk still seems simpler than scrolling through screen after screen of material. This process may be repeated several times depending upon the conclusions desired or the amount of material generated by this sorting process. However, its ultimate purpose is to identify statements from the raw data to use in the report. Once these statements have been identified, the researcher may either use the erase functions within *Wordstar* to eliminate material which is not to be used or return to *dBase II* and use the copy command to produce files which contain only the selected quotes.

The beauty of these compatible systems is that once the pieces of qualitative data have been identified that most strongly support the conclusions or best illustrate the point to be made, it is very simple to use the *Wordstar* "read file," "block," and "move" commands to transfer the selected material from a data file to a text file. Reporting can be as easy as creating a paragraph or two describing the findings and transferring in a dozen or so quotations to support the conclusion.

An Example

Naturalistic inquiry produces volumes of data. Unfortunately, researchers often magnify this characteristic by expanding it even further by needless duplication and transcriptions. In naturalistic inquiry, the data analysis stage should be one of data reduction and manipulation. A recent statewide evaluation of the adult basic education program in Texas provides an example of how *dBase II* and *Wordstar* can be used to enter data, manipulate it, and then structure it into a final report. This evaluation used a naturalistic design to examine the comprehensiveness of the system for delivering literacy services throughout the state. During a 6-month period, over 200 students, teachers, administrators, aides, board members, state agency personnel, and community linkage people were interviewed. The research team consisted of three university professors and two graduate students. As the data were being collected, the project leader designed a *dBase II* structure for entering data and a list of potential "keywords" for coding the data. Each researcher was responsible for entering his/her data into dBase II. Since all of the interviews were tape recorded, one merely listened to the tapes and typed significant quotations into the file. Another looked at the quotes from his notes and referred to the tapes as indicated in the notes at the time of the interview. Another took careful notes during the interview. He entered some of the cases directly from these notes; for others he jotted the keyword by the comments so they could be entered by a more efficient typist. Two others wrote out their quotations after referring to their notes and tapes; these were then entered by the secretary. As new categories emerged from the data, new keywords were created and circulated among the research team. As a result of this process, diverse styles were accommodated for entering data in a common form. After data entry was completed, the project director collected all of the floppy disks, combined small files, and proceeded with the data analysis.

The first task was to sort the data into categories and to analyze the data for central themes. This was done by using the keywords and the "copy" command. With a command, keywords were used to locate quotes on a common topic in each of the files of the research team members. These quotes were printed into separate ASCII files for each team member. Using *Wordstar* and the "read" file command, the files pertaining to a keyword or a combination of keywords were merged into one file. This file was then converted to a hard copy on the office printer. Team members used this printout to analyze the data and to generate discussion. Once conclusions were reached concerning the data and explanatory quotations were selected, the "write" file command of *Wordstar* was used to create new files which contained the quotations destined to be used in the final report. Since only one block of information can be written to a file with this command, it was often necessary to create several small files such as Quote1, Quote2, and Quote3. These were then read into the final report file. At this time, the text concerning the ideas and conclusions drawn from the quotations was added. Also any labeling of the quotes or minor editing that was required was done. Through this process a 95-page evaluation report was constructed. Consistent with the goal of naturalistic inquiry, this report contained hundreds of direct quotations which allowed the people affected by the program to tell their story. The report clearly states that education is a human enterprise and provides vivid documentation of the strengths, weaknesses, accomplishments, and needed areas of improvement for the program.

Helpful Tips

The microcomputer has sanctioned creative attempts at problem-solving. Teachers often state that there is a correct or best way to solve a problem; doing numerous calculation problems in math class or correctly diagraming sentences in English class are examples of this approach. However, like writing a proof in geometry, many different paths can produce successful results when working with a microcomputer. One seldom finds the successful path with the first effort. However, each new experience provides new knowledge and insights for more quickly and cleverly solving future problems. The following tips were learned through working with *dBase II* and *Wordstar* on the adult basic education naturalistic evaluation. While each example represents only one approach to a problem, they are presented here to demonstrate the power of the systems, to improve the efficiency of future research, and most importantly to stimulate additional thinking.

Trimming the file. Data based files can quickly become very large. Regardless of the amount of data entered for each case, the case occupies the full amount of space allocated for it in the original structure. Since large blocks are placed in the structure in order to have sufficient room for quotes, data based files tend to be large. However, smaller, working files can be created by using the "copy" command. The new file can be custom designed to contain only the quotes and identification fields that the researcher desires. In this process of creating a new and more specific file, a variety of combinations are possible. Keywords from within a field in the structure may be combined or various fields may be linked. The copy command will allow the creation of a new data based file which can be used by *dBase II* or the creation of an ASCII file which can be read by *Wordstar*. Whatever the unique needs are, a specific file can be created for it. The naturalistic researcher using this system will quickly realize that the "copy" command is the most versatile and powerful for manipulating qualitative data.

Creating new files. Once the hard copy has been analyzed and data selected for inclusion in the final report, new files may be created either from *dBase II* with the "copy" command or from *Wordstar* with the "block" and "write" file commands. Since it is somewhat cumbersome to move around within large *Wordstar* files, the "copy" command in *dBase II* will generally be used to extract information from large files. In order to copy one specific quote from a large file, an additional piece of information about the specific quote such as the record number is helpful. This information should be requested and printed on the hard copy when the initial copying is done. For smaller files, it may be quicker to use the "block" commands in *Wordstar* to mark the quotes that are desired. Two techniques can be used here. One is to arrange all of the quotes in the order desired at some specific place in the file; this is usually at the end of the file. The entire file can then be marked and written to a separate file for later inclusion in the final report. The other technique is to mark each desired quote and write it to a separate file. This creates several small files in which each has a single quote. These can then be read into the final report file as needed. To save keystrokes, remember to use short names with numbers such as Q1 and Q2 (quote number 1 and 2) for these files.

Index vs. sort. Sophisticated data management systems allow the rearrangement of data by sorting and indexing. Sorting physically re-arranges the data in the file in the order dictated in the sorting instructions given by the researchers. Indexing merely creates a supplementary file with instructions for the system on how to order the data. Sorting is a slow process. Indexing is fast. However, it requires a slight amount of disk space, and the index must be requested each time the file is used. Fortunately, the experienced user will quickly discover that the most useful way to re-arrange data is with the "copy" command. Consequently, neither the sorting nor indexing functions need to be used much with naturalistic inquiry.

Field length. One of the major advantages of a data management system is that the fields for the data can be custom designed to fit the researchers' unique needs. However, care should be taken not to make fields unnecessarily large. Regardless of the information in them, fields take up the full allotted space in storage. In addition, search and sort commands do not work on fields over 100 characters long. On the other hand, fields which are too short force the research to devise plans for linking files together. Unfortunately, it is easy to forget the system concocted while entering data for linking segments, and it is easy for this data to be separated in the copying and analyzing processes. Because of these pitfalls, care should be taken in designing the structure of the fields.

Changing the structure. If the field lengths are not convenient or if additional fields are needed, it is possible to change the structure. While this procedure is rather simple, care must be taken to assure that all of the data entered in the data based file is not lost. Since the "modify structure" command destroys all data in the file before making the requested changes in the structure, a temporary data file must be created. After the structure is modified, the data should be copied back into the file with the "append" data command. The needed information can then be added to the new files with the "edit" command. If much similar information is to be added to the new fields, the "change" command may be helpful.

The comma. If data are to be moved in and out of the *dBase II* file with the "copy" and "append" commands, the comma should not be used as a delimiter for the fields in the process. Since the quoted data will undoubtedly contain numerous commas, the use of the comma as a delimiter can severely confuse the program in reading the data back into the data based file.

Set "carry" on. Naturalistic data seeks to elicit comprehensive data from a limited sample. Therefore, each person in the sample usually has several quotes that need to be entered into the data management system. To identify the quote, all the demographic variables for this person must accompany each quote. The repetition of this data in the file is facilitated by the "carry" command. By setting the "carry" command to "on," all information from the previous record is carried forward to the new record. Therefore, only the fields that are different need to be modified. This command can save a tremendous number of keystrokes when entering data.

Editing. Data may be modified after it has been entered into dBase II. The "locate" and "find" commands can be used to locate the first word of fields less than 100 characters. Once the record number has been found, the "edit" command can be used.

RAM speed. Although computers work rapidly and can perform many tasks faster than people, they cannot match the human brain in creative thinking. While manipulating the data, ideas churn in the researchers head. Since it is easy to lose an idea while waiting on the machine, speed in the computer is an aid to research. The speed of the *dBase II* operation can be increased from five to seven fold by using RAM memory. The use of RAM also reduces wear on the disk drives. Since *dBase II* uses a small buffer for its current information, it must constantly return to the floppy disk when copying or sorting. This mechanical process is no match for the speed and quietness of the electronic memory.

The half-full disk. When entering and manipulating qualitative data, it is easy to overfill the floppy disk. Files grow rapidly, every time a file is copied, the storage space for the record is doubled. Since *dBase II* commands cannot complete their operation if there is not adequate disk space to store their newly created file, it is a sound practice to only fill half of the disk with data. The remaining space is then available for data manipulation.

Comments field. Often times while entering the data, the researcher will have an insightful observation about the data. It is a good practice to document this insight and to link it to the data. This can be done by creating a "comments" field in the original structure. This field is reserved for special comments the researcher wishes to make. Since it is used sparingly, it should be keep under 100 characters.

Conclusion

Microcomputers can be a effective tool for allowing the researcher to exert control over qualitative data. Naturalistic inquiry generates voluminous amounts of data, and data management requires an immediate strategy for the reduction of data into meaningful units. Equipped with compatible data management and word processing systems, the researcher can manipulate the data from its initial entry to its inclusion in the final report. At each stage of the research, information can be sorted, arranged, and printed as needed. The ability to move data between the data management system and the word processing system not only allows the researcher to quickly follow any desired line of thinking, but it also eliminates retyping. Best of all, the use of these systems is not limited to manipulating interview data; they can be used with any naturalistic applications such as evaluations or historical research which deal with qualitative data. Researchers with naturalistic designs will need to find new uses for their old shoe boxes once they turn on the microcomputer.